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Geothermal Industry Position Paper

EPA Regulatory Options and Research and Development Information Needs

EPA Geothermal Working Group

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August 1977

Geothermal Industry Position Paper

EPA Regulatory Options and Research and Development Information Needs

by

EPA Geothermal Working Group

EPA Contract No. 68-01-3188
EPA Project Officer: Gregory D'Alessio

for
Environmental Protection Agency
Office of Energy, Minerals and Industry
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Washington, D.C. 20460

FOREWARD

This document presents the approach of the Environmental Protection Agency to the problem of regulating an evolving but essentially undeveloped industry, namely that which uses geothermal energy technology.

While the Energy Research and Development Administration has provided a focus for Federal initiatives in this area, a large number of private interests, both large and small, are engaged in exploration and development of this presently untapped energy resource.

Extensive exploration for geothermal resources is taking place throughout the Western U.S. and significant demonstration and commercial projects are projected to take place within several years. Much of this activity will take place on Federal lands.

Because of this and the present uncertainty over the environmental impact of various geothermal technologies, EPA has developed this position paper as a first step toward guiding the evolution of the geothermal energy industry in directions which will adequately protect the environment and human health.

The geothermal energy industry is but one potential industry based on emerging energy technologies funded under the National Energy Plan. By taking the opportunity to address this technology in its formative stages, EPA can expedite the environmentally proper commercialization of this energy resource and avoid economically undesirable pollution control backfitting requirements in the future.

Gregory J. D'Alessio

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Chairman
EPA Geothermal Working Group

ABSTRACT

The environmental impact of geothermal energy development may be less intense or widespread than that of some other energy sources; however, it is the first example of a number of emerging energy technologies that must be dealt with by EPA. EPA may consider a spectrum of options ranging from a posture of business as usual to one of immediate setting of standards, as favored by ERDA. The paper discusses the regulatory approaches and the potential problems that geothermal energy may present in the areas of air quality, water quality, and other impacts. It is recommended that a coordinated program of research be drawn up, comprised of specific research projects, the types of geothermal resource to which they apply, and the date by which the information is required.

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Thanks are also due to Mr. George Swetnam of the METREK Division of the MITRE Corporation who researched and produced much of the technical material in the Position Paper.

SECTION 1

INTRODUCTION

The Geothermal Advisory Council (GAC)* has been established as the forum in which the Energy Research and Development Administration (ERDA) will coordinate interagency activities relating to its development of viable geothermal energy technologies. The Administrator of the Environmental Protection Agency (EPA) has designated the Assistant Administrator for Research and Development as his representative to the GAC, which is chaired by the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems of ERDA. EPA is also represented on the GAC by its Office of Planning and Management on matters relating to Agency policy.

As one of its initial actions, the GAC requested EPA's position on environmental standards for the emerging industry, urging EPA to immediately set interim standards. In order to initiate the formulation of an Agency-wide position on this question, within the context of existing priorities and commitments, EPA has formed the Geothermal Working Group from representatives of the concerned program and enforcement offices (Appendix A). This group was formed to address the following questions:

1. What potential environmental problems does EPA foresee as associated with the emerging geothermal industry?

2. What courses of action are open to EPA in the Research, Development, and Demonstration phase of geothermal development in order to control and minimize the environmental impacts of the mature commercialized phase of this emerging industry?

3. Given a course of action, an indication of its relative priority and the immediacy of its need, how can EPA best approach the question of environmental guidance and regulation and required supporting research for the geothermal industry?

This document is the first step in a process that will, through discussions within EPA and dialogues with ERDA, answer these questions.

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*The name of the Geothermal Advisory Council (GAC) has been changed to the Interagency Geothermal Coordinating Council (IGCC). Wherever appearing in this document, the term GAC should be considered as the same as IGCC.

I. PURPOSE

This paper presents an appraisal of the environmental problems presented by geothermal energy, as seen by an EPA Working Group composed of representatives of:

- The Office of Water and Hazardous Materials, represented by the Office of Water Planning and Standards (OWPS) and the Office of Water Supply (OWS),
- The Office of Air and Waste Management, represented by the Office of Air Quality Planning and Standards (OAQPS) and the Office of Radiation Programs (ORP),
- The Office of Planning and Management, represented by the Office of Planning and Evaluation (OPE),and
- The Office of Research and Development, represented by the Office of Energy, Minerals, and Industry (OEMI).

The paper also presents the recommendation of the Working Group to the Agency for consideration in choosing an Agency-wide approach to the geothermal industry. Such a unified approach will assist the program offices by providing a coherent framework for planning. It will support the regional and enforcement offices by providing the basis for a coherent Agency approach. It will aid the Office of Research and Development by indicating a favored regulatory approach to the problem toward which supporting R&D can be focused. Finally, it will assist the geothermal industry by initiating the coordination of EPA action on pollution limits and required control techniques.

II. OBJECTIVE

The objective of the paper is to identify EPA's areas of concern and responsibility and to present this position to the Agency for approval and incorporation into Agency plans. The paper will also serve to consolidate EPA's view for the Geothermal Advisory Council by providing the following information:

- A preliminary EPA review of specific environmental impacts associated with geothermal energy development,
- An outline of the regulatory pathways and non-regulatory options available to the respective program offices of EPA, with specific recommendations,

- An outline of the timing of specific ERDA development plans and the associated EPA decision deadlines required for guidance to the developing geothermal industry, as well as to regional and enforcement offices,

- An outline of information needs associated with preliminary problem evaluation and with supporting the specifically recommended regulatory approaches, and

- A list of research needs and milestones which EPA will need to meet its information and decision deadlines.

SECTION 2

EPA STRATEGY

I. WHY EPA SHOULD ADDRESS GEOTHERMAL ENERGY

Among the new sources of energy that can help supply the future needs of the United States is geothermal energy, the heat contained in the earth's interior. The total supply of such energy is uncertain, partly because many undiscovered resources are believed to exist and partly because new techniques are needed for extraction and use. However, several geothermal fields, including one in the U.S., have proven commercially successful, and research is under way to increase the number and kinds of resources that can be tapped.

Although the environmental impact of geothermal energy development may be less intense or widespread than that of some other energy sources, there are several reasons why it should receive prompt attention within the Environmental Protection Agency. The national emphasis on energy independence has focused attention on unconventional energy sources, and the Energy Research and Development Administration has under way programs to develop the most promising candidates, among which is geothermal energy. To the developer of a new energy technology, environmental protection presents a set of problems that must be solved, but that are ill-defined both because the environmental effects may be unclear and the stringency of EPA's eventual regulatory actions may be hard to judge.

A. Organizational Background

Because geothermal energy raises questions that concern a number of Federal agencies, the interagency Geothermal Advisory Council (GAC) has been formed to facilitate the search for appropriate answers.

The GAC was formed to coordinate those Federal plans, activities, and policies that are related to or impact on geothermal energy. The Council is comprised of three panels, a Resources Panel, a Research and Technology Panel, and an Institutional Barrier Panel. The Institutional Barrier Panel is responsible for assessing legal, environmental, regulatory, and other aspects of Federal, state, and local government policy. This panel, chaired by the FEA representative, recommended that the GAC promulgate interim environmental standards for the geothermal industry.

ERDA and the Federal Energy Administration have, through the GAC, pressed EPA for action regarding the environmental regulatory

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guidelines that may be required of geothermal energy development in order that the emerging industry might develop within clear environmental limits. It was argued that failure of EPA to respond will force geothermal energy development to proceed without knowledge of the protective measures it must eventually incorporate or the costs they will exact, and will, for lack of Federal guidance, cause individual states to set standards which may vary greatly, thus undermining confidence and investment potential in the industry.

Geothermal energy conversion is but the first of a number of emerging energy technologies to require formal consideration by EPA for possible regulatory actions. There are three characteristics which are common to all the new energy technologies and which should be addressed by EPA in formulating its regulatory approach:

- Information is scarce on pollutant emissions and effluents, on concentrations, and on control techniques for the new developing technologies being considered by the industry and ERDA.

- Government-stimulated development affords an opportunity for EPA to influence the development and demonstration of technologies which are inherently more environmentally protective than other alternatives.

- Government-stimulated development plans for new technologies do not in general allow enough time for EPA to gather information and develop regulatory guidelines prior to commercial deployment without a special effort.

II. EPA'S APPROACH TO THE PROBLEM

A. Background

EPA finds itself in a new role in the scheduled development of geothermal energy. In the past EPA has generally been in a reactive mode, attempting to correct environmental damage after the fact. In the emerging energy technologies, including geothermal energy, the Agency has the opportunity to minimize eventual adverse effects and control costs by advanced planning. It can do this in such a way that it fosters energy technology development and guides it along environmentally protective paths. In order for the Agency to take the initiative in the environmental area it must do so now, in the early stages of energy technology development. Research is required to support the regulatory and guidance mechanisms the Agency chooses to employ. Because time is an important factor in research, it is necessary for EPA to make immediate decisions concerning its approach to geothermal energy and the direction of associated

supporting research. The lack of a coordinated geothermal position will put EPA in a less effective reactive mode, reducing EPA influence over the type of processes and equipment selected.

The accelerated pace of geothermal energy development now being considered by ERDA can be expected to have important effects on the choice of action open to EPA. Because environmental protection criteria are a matter of concern to geothermal energy developers and their potential financial backers, whatever approach EPA takes is bound to have some effect on the rate of development.

B. The Geothermal Working Group (GWG)

In order to address this problem, the Deputy Assistant Administrators of the concerned EPA program offices and ORD met to discuss the proper response to GAC's recommendations, and established a Geothermal Working Group (GWG) within EPA to identify the environmental problems foreseen for the geothermal energy industry, the appropriate regulatory pathways that EPA might wish to adopt, and the consequent information and research needs which might be addressed, both by EPA and by other agencies. The GWG was also instructed to address itself to the question of how EPA should approach environmental regulation and guidance for the geothermal industry as a part of the response to the GAC. The issue of regulatory options is significant in that geothermal energy represents the first example of a number of emerging energy industries. These industries are now choosing among alternative energy technologies, and EPA needs to be informed in order to influence their choice.

III. RECOMMENDED STRATEGY

The Geothermal Working Group believes that immediate setting of geothermal environmental standards is unnecessary. This is because (except in case of dry steam) geothermal technologies are not developed well enough for adequate pollutant and effects information to be available. Adequate and timely pollutant and effects information should be developed in parallel with the various evolving geothermal technologies, in order that environmentally protective options may be demonstrated and identified.

The GWG has also concluded that EPA should not deal with geothermal facilities only on an ad hoc basis as ERDA and industry plans become apparent through New Source Review, EIS Review, and other actions. Without advance national planning and guidance, inconsistent approaches might evolve in different regions, especially because complete information is not available to ensure the applicability of existing regulatory and review procedures to the diverse set of

geothermal resources and conversion technologies. Where new extraction techniques are being developed, the development period allows time for EPA to gather specific information on environmental impacts, control techniques, and cost factors.

Even though it is inadvisable to develop standards immediately, the high national priority on alternative energy sources requires that EPA give special attention and assistance to the development of geothermal energy, as well as other new energy technologies. Therefore, the GWG recommends a strategy of cooperative Research, Development, and Demonstration (R,D&D) with ERDA.

A positive approach to geothermal environmental regulation is to regulate known problem pollutants while collecting data on other emissions and testing control technology. This approach must involve ERDA's cooperation in thorough emissions characterization and control technology evaluation at the pilot and demonstration plant level. It minimizes EPA program resource commitment, yet offers a comprehensive assessment of environmental, health, control, and cost factors prior to standards development. It provides EPA with the opportunity to influence the evolution and choice of new geothermal technologies toward environmentally protective alternatives. It provides the agency with an up-to-date information resource on specific technologies that can be utilized in the normal regulatory and environmental impact statement review processes. Environmental Impact Statement review, New Source Review, Non-Significant Deterioration Review, and National Pollution Discharge Elimination System Review are required at both the demonstration and first-generation commercial scale, so that basic regulatory procedures would still be involved. But, it is not clear how completely these are applicable to the impacts of geothermal development.

In order to implement this strategy, the GWG recommends that EPA take the following steps:

- Establish a formal working relationship between EPA and ERDA's Division of Geothermal Energy that will provide for continual contact at the technical level as an integral part of the EPA/ERDA R,D&D program.

- Issue by mid-1977 a preliminary guidance manual on which to base the design of demonstration installations, and to provide environmental criteria for permit issuance and EIS review.

- Adopt a regulatory* mission-oriented research program, undertaken in cooperation with ERDA's development program and structured to generate environmental impact and control information as it is required by the development schedule for geothermal energy sources.

- Evaluate, according to a long-range, but flexible, schedule, the need for special standards based on information gathered.

- Develop, where necessary, standards in time to provide adequate environmental protection measures in advance of commercialization.

*In this document, 'regulatory' is understood to include standard setting as well as formal regulation.

SECTION 3

EPA PLAN OF ACTION

To implement the geothermal strategy discussed above, EPA must continually track the ERDA plan for geothermal development and select the best program of cooperation and guidance.

I. ERDA'S GEOTHERMAL DEVELOPMENT PLANS

Figure 1 presents a summary of one national development scenario under consideration by ERDA. It is based on the following assumptions:

(a) An attempt is made to reach the goals cited in Definition Report: Geothermal Energy Research, Development & Demonstration Program (ERDA-86), subject to reasonable development cycles.

(b) Each resource site is initiated with a small (50 MW output) plant, with development on a commercial scale after successful operation has been demonstrated.

(c) Development of resource sites is keyed to current production or exploratory drilling operations.

The implication of such a scenario to EPA is that the next five years are expected to see the development of several fundamentally different types of geothermal resources such as liquid-dominated hydrothermal* (for which few data and only one environmental installation exist), as well as geopressured and hot dry rock, for which virtually no environmental data exist and no installations are in operation.** The development of hot dry rock systems is not envisioned until 1985, but thermal extraction experiments which are planned for 1978 and 1981 will merit EPA's attention. Even in the case of existing technology for vapor-dominated systems at the Geysers, environmental problems due to H_2S emissions have arisen and must be solved if development of this resource is to recommence in an environmentally acceptable manner.

Figure 2 presents the estimated growth curve of geothermal energy implicit in ERDA-86. Because of the steady pace of anticipated growth, EPA action within the next five years will be in time to affect the majority of the capacity projected for 1990.

*ERDA includes volcanic resources in the hydrothermal part of its program.

**Locations of the currently known and potential geothermal resource areas appear in Appendix B.

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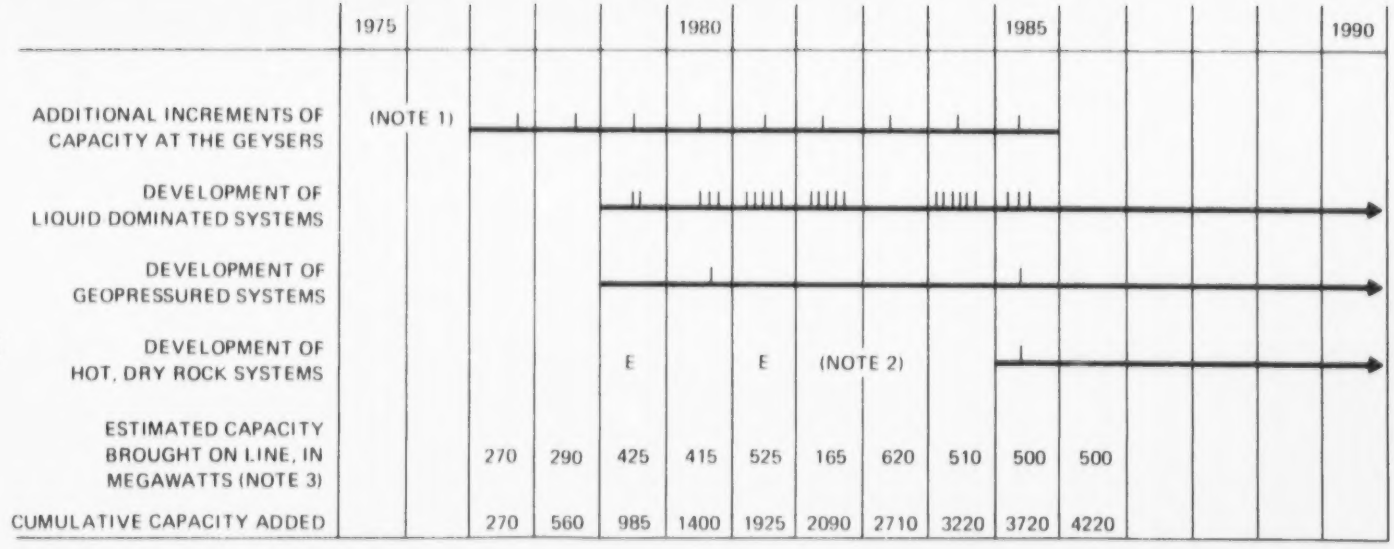
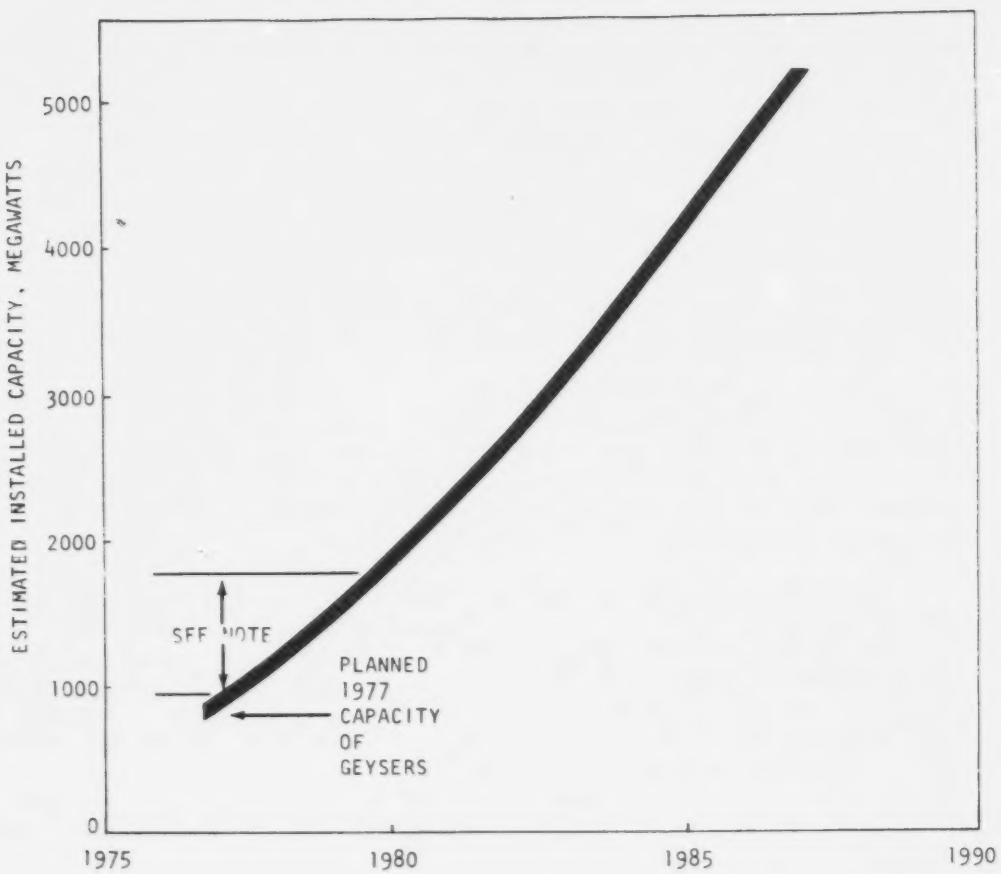

1975
1980
1985
1990
ADDITIONAL INCREMENTS OF CAPACITY AT THE GEYSERS
(NOTE 1)
DEVELOPMENT OF LIQUID DOMINATED SYSTEMS
DEVELOPMENT OF GEOPRESSURED SYSTEMS
DEVELOPMENT OF HOT, DRY ROCK SYSTEMS
E
E
(NOTE 2)
ESTIMATED CAPACITY BROUGHT ON LINE, IN MEGAWATTS (NOTE 3)
270 290 425 415 525 165 620 510 500 500
CUMULATIVE CAPACITY ADDED
270 560 985 1400 1925 2090 2710 3220 3720 4220

NOTES:
1. EACH TICK REPRESENTS ONE PLANT BROUGHT ON LINE
2. E DENOTES A THERMAL EXTRACTION EXPERIMENT
3. ESTIMATES NOT AVAILABLE BEYOND 1987

FIGURE 1
NEAR-TERM SCENARIO FOR GEOTHERMAL ENERGY DEVELOPMENT



NOTE: GROWTH THROUGH 1980 IS CHIEFLY FROM ADDITIONS TO THE GEYSERS, PLUS EARLY IMPERIAL VALLEY INSTALLATIONS

FIGURE 2
ESTIMATED NATIONAL GROWTH OF GEOTHERMAL ELECTRIC POWER

II. IMPLICATIONS OF THE ERDA PLAN

When the process of developing environmental regulation is compared to the planned development of geothermal energy, it becomes evident that special measures will be required to avoid the risk of an uncontrolled environmental impact. As the following sections make clear, appropriate regulation will require a considerable research effort. In order to develop this information on an industry-wide/ Federal basis and in a timely manner, it is recommended that a mission-oriented program of coordinated research and regulatory planning be adopted, as discussed below.

III. A MISSION-ORIENTED APPROACH TO REGULATORY PLANNING AND ENVIRONMENTAL RESEARCH FOR THE EMERGING GEOTHERMAL INDUSTRY

An orderly, Agency-wide approach to an emerging industry demands a coherent set of program office plans. These plans should be based on a clearly-defined regulatory approach and should delineate specific decision points related to ERDA's geothermal development program. Only in this way can a balanced environmental research program be formulated.

The development of a balanced research program is a challenging task of weighing the areas of concern against the available funds. In order to maximize the effectiveness of EPA efforts in view of the accelerated pace of geothermal resource development, the program should be mission-oriented, that is, environmental research should be planned to focus on the most critical areas of environmental concern and Agency responsibility. Research should be an integral element in a program arranged to develop specific knowledge at the time it is needed for regulatory decision-making related to geothermal energy development on an industry-wide basis. Development of such a program involves a number of tasks:

A. Problem Evaluation

The first step is examination of the development scenarios in order to recognize specific environmental problems and requirements for guidance and regulation for development of each type of geothermal resource. This assessment will be developed by ORD in concert with and for review by involved program and regional offices.

B. Regulatory Pathways and Guidance

From a knowledge of the environmental problem, EPA can proceed to determine the appropriate form of regulatory action, and how the necessary environmental action is related to generic geothermal

development schedules. In view of the anticipated early development of liquid-dominated hydrothermal sources, it may be difficult to issue definitive regulations for initial installations in the time available. In such cases, a target date for EPA evaluation of the situation should be proposed, supplemented by early guidelines for the more critical aspects of the problem.

C. Regulatory Decision Schedule

Having decided upon the approach best suited to the resource types and their environmental impacts, EPA can draw up a regulatory decision schedule for each type of geothermal technology. This schedule should be incorporated into the plans of each respective regulatory office within EPA. This schedule will provide guidance for each resource type late enough to profit from information gained from initial experiments and installations, but early enough to affect the choice of which of new technology should expand on a commercial scale. This schedule should be updated annually to reflect actual industry progress.

D. Recognition of Required Supporting Information

From the schedule of expected activity, the next step is to establish the information required to support each stage. The required information will depend on:

(a) The resource type;

(b) Anticipated emissions and other effects (problem assessment);

(c) Whether the development is a thermal extraction experiment, a pilot or demonstration plant, or a commercial power station; and,

(d) Whether interim guidance, standards or final regulatory action is appropriate.

These information needs will be based on the favored regulatory pathway chosen by each respective regulatory office within EPA.

E. Identification of Research Program Needs

Once the pattern of information required by the regulatory offices and associated deadlines have been determined, it should be examined for areas of common need among geothermal resource types. A special effort must be made to determine what information is available, or may be expected to become available from environmental

research pertaining to other research areas. The end product of this step is a scheduled list of research information needs that are unique to geothermal energy or which have higher priorities in the geothermal field than in other research areas. The list should be classified not only by when items are needed, but also according to the specific geothermal resource type to which they apply. Research topics common to more than one resource type are grouped together, with a schedule determined by the resource type having the earliest anticipated development.

F. Research Program Definition

When the above process is complete, EPA will be in position to combine the specific research topics into a coordinated research program. This should be done in the light of environmental research being performed by other agencies and industry, in order to minimize impact on R&D resources. This step will involve comparing the requirements of time and information with the funding resources and organizations available to perform the required work. EPA offices which have a strong internal capability will wish to divide the program into internal and contractor-supported efforts to make the best use of both resources. Research topics having a common theme may be combined and awarded to specific contractors with special ability in the field. The program subjects at this point should include the title of each effort, objectives of the research, relation to specific resource types and problems, the end product expected of the research unit, and the required completion date.

A mission-oriented regulatory planning and research program will support EPA's responsibilities and activities in geothermal environmental protection and regulation, by helping to ensure that the required information is available when it is needed. Because it is coordinated with ERDA schedules and oriented to EPA's mission, it will provide a firm, logical basis for determining long-term R&D budget requirements.

SECTION 4

OUTLINE OF A MISSION-ORIENTED APPROACH TO GEOTHERMAL ENVIRONMENTAL REGULATORY PLANNING, RESEARCH, AND DEVELOPMENT

Based on the factors discussed in the preceding section, the Geothermal Working Group has recommended that environmental aspects of the emerging geothermal industry should be addressed on a mission-oriented basis. That is, environmental regulatory planning and its supporting R&D effort should be coordinated with the evolving development schedule of alternative technologies and resource types as planned by ERDA and the industry. This section presents the GWG outline of the mission-oriented approach. It evaluates the significance of geothermally related environmental problems as understood at present, outlines the factors determining the best approach to regulation, and presents a brief list of information needs around which an R&D program should be formulated to support the recommended regulatory approach. The anticipated impacts of geothermal energy are discussed along media lines: air quality, water quality, ground water, radiation and other effects.

I. AIR QUALITY

A. Problem Evaluation

Geothermal fluids are seldom clean, but commonly contain a number of chemical elements and compounds, some of which may escape from the exhaust steam, cooling towers, or by other paths. Among those known to escape in gaseous form are hydrogen sulfide, mercury, and ammonia. Radon will be discussed in the section on radiation. The environmental threat to air quality has not been fully assessed, but attention has already been drawn to the problem of hydrogen sulfide.

1. Hydrogen Sulfide in Vapor-Dominated Hydrothermal Sources

Most of the available information on geothermal pollution in the U.S. comes from The Geysers, California, where 15 year old technology has utilized a rare, vapor dominated resource since the 1960's in the only commercial U.S. geothermal power plant. At The Geysers, the steam contains from 5 to 1600 ppm H_2S depending on the well, averaging 222 ppm. There are a total of about 70 wells extending over about 1900 hectares. An average of 1.8 to 2.3 kg of H_2S per MWh is released to the atmosphere, mainly from the condensate cooling towers. Uncontrolled, The Geysers at 400 MW emits 725 kg of H_2S per hour. A large 900 tonne per day, uncontrolled kraft pulp mill would emit 360 kg of H_2S per hour.

The Geysers has a history of odors, and there are complaints today directed at Pacific Gas and Electric (PG&E), the owner. They are required to meet the California ambient H_2S standard of 30 ppb, an "average" odor threshold limit. Carl Weinberg, PG&E, estimates that this limit is probably exceeded from 1/2 to 1 percent of the time, mainly due to weather conditions. It is not known whether H_2S may create any more formidable problem than odor in the concentrations released from geothermal energy applications. Concentrations of 300 ppb have reduced growth in alfalfa and grapes. The gas is fatal to humans in 30 minutes at 600,000 ppb.

The average H_2S content of other dry-steam fields varies from 186 ppm at Showa-shinzan, Japan to 900 ppm at Lardarello, Italy. Because of the large differences in chemistry of various geothermal sites, this resource may prove analogous to low and high-sulfur coals. Dr. Martin Goldsmith, California Institute of Technology, estimates that the amount of sulfur released at The Geysers is equivalent to that emitted by an uncontrolled fossil-fueled plant of the same size burning low-sulfur oil. Appendix C discusses the status of H_2S control technology at The Geysers.

2. Hydrogen Sulfide in Liquid-Dominated Hydrothermal Sources

Hydrogen sulfide is also present in many liquid-dominated hydrothermal sources, but only the one at Wairakei, New Zealand, has a long experience of commercial exploitation. This plant, of 145 Megawatts output, releases H_2S at about 14 kg/hour in the stack gas. At the developmental installation at Cerro Prieto, Mexico, a 32 Megawatt output unit is reported to emit 355 kg of H_2S per hour. The lack of proportion are due largely to differences in source concentrations. Similar levels could cause significant problems at U.S. sites across the border from Cerro Prieto in the Imperial Valley, without appropriate controls.

3. Mercury

Mercury is present in many geothermal wells, and early data indicate that it tends to follow the vapor phase in flashing and evaporation. Some measurements of mercury emissions are now being collected by Battelle-PNW at The Geysers and at Cerro Prieto. The results should assist EPA in determining whether an environmental problem exists.

4. Other Contaminants (e.g. Carbon Dioxide, Ammonia, Boron)

Geothermal hydrothermal sources frequently contain a number of other substances. Sources vary widely in chemical constitution; this fact should be taken into account in estimating the impact of geothermal development. Appendix D presents a list of chemical elements and compounds that have been reported in geothermal fluids.

5. Geopressured and Hot, Dry Rock Sources

Other types of geothermal sources, such as geopressured and hot, dry rock, are still in the early planning stages. The probable effect of such sources on air quality is not clear.

6. Overall Situation Assessment of Existing Locations

The only operating U.S. geothermal power plant is in California, where PG&E must meet a state-imposed odor threshold regulation, and the H_2S odor threshold is well below the levels at which toxic effects occur.

Other air pollution problems have not become apparent, but may be involved in development of sources other than The Geysers, and H_2S may present health or welfare (e.g., crop and materials damage) problems at other sources. The GAC has now specifically raised the question of the need for an ambient H_2S standard that would provide a reference which states might adopt and that would allow the expanded

development of The Geysers from 500 MW to 2300 MW over a 10-year period* if the State of California were to reevaluate its regulations.

B. Guidance and Regulatory Actions

1. Guidance

The first step in terms of Agency commitment requires an active role in advising its own regional and enforcement offices, state control agencies, ERDA, and the industry. In addition to gathering air data, EPA would analyze it and make recommendations. The extent of involvement could vary, but as a minimum would require an initial effort to obtain and evaluate existing data on known geothermal air pollutants and effects. Direct input to ERDA programs and state air pollution control agencies would be the next step. A guideline manual provides the technical basis for this effort. At the highest level of effort under this approach, EPA would advise agencies and the industry of appropriate ambient or emission limits, recommend control technology research to ERDA, perform additional research in house, and take an active role in geothermal-related environmental decisions.

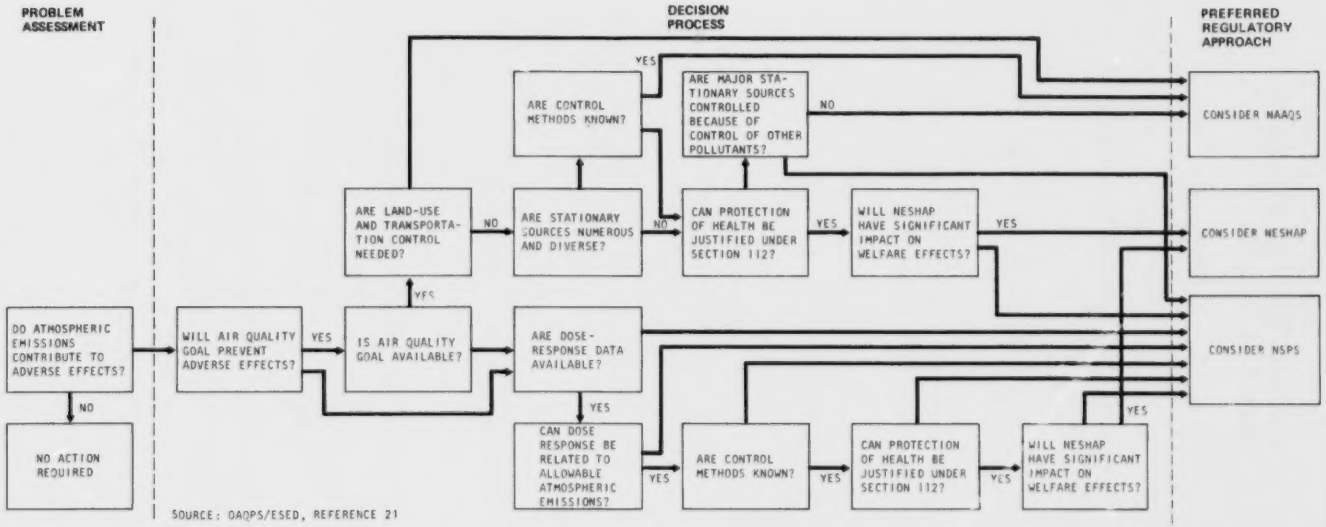
2. Permits

The GWG and the Division of Stationary Source Enforcement do not consider the present mechanisms of New Source Review and Non-significant Deterioration Review to be an adequate approach when applied to geothermal installations. New Source Review addresses only the pollutants for which air quality criteria have been established: carbon monoxide, particulates, sulfur oxides, hydrocarbons, oxides of nitrogen, and photochemical oxidants. Non-significant Deterioration Review addresses only sulfur dioxide and particulate emissions. None of these pollutants appears likely to be significant in geothermal industry applications. Thus, New Source Review and Non-significant Deterioration Review--as presently applied--would serve merely to give rubber-stamp approval to a geothermal installation.

3. Standards Pathways

The Office of Air Quality Planning and Standards (OAQPS) has a number of regulatory options regarding pollutant control, depending on the type of source, effects, and other factors. Figure 3 shows

*Source: O. Citron, et. al., Report on the Status of Development of Geothermal Energy Resources in California, 5040-25, California Institute of Technology, Pasadena, California, 31 March 1976.



SOURCE: OAQPS/ESED, REFERENCE 21

NOTES:

1. Where "yes" or "no" is indicated, answer must be conclusive. Answers such as significantly, maybe, perhaps, could be, or conclusive opposites to the indicated answer follow the undesignated path.
2. NAAQS means Section 108, 109, 110 as well as Section 111(b).
3. NSPS means Section 111(b) and Section 111(d) as well as Section 15.
4. NESHAP means Section 112 and Section 111(b).
5. Mobile means Section 201
6. "Land-use and transportation controls" means any measures other than permanent emission reduction, such as: intermittent control, tall stacks, traffic control, fuel switching, development of transit systems, site selection, etc.
7. The term air quality goal means concentration-time relationships which separate effects from no-effects; contamination to the goal is permissible.
8. Dose-response means a relationship between pollutant dose and effects, independent of exposure route.

FIGURE 3
PREFERRED STANDARDS PATH ANALYSIS FLOW CHART FOR GEOTHERMAL AIR QUALITY PROTECTION

the standards path analysis applicable to geothermal industry sources used by OAQPS. The principal regulatory possibilities are:

- Establishment of National Ambient Air Quality Standards (NAAQS) under Section 108 of the Clean Air Act.
- Establishment of New Source Performance Standards (NSPS) under Section 111 of the Act.
- Establishment of National Emissions Standards for Hazardous Air Pollutants (NESHAP) under Section 112.

Under each of these regulatory approaches, a wide range of standard-setting activity is possible:

- Standards can be established based on existing information (e.g., 90% control of hydrogen sulfide emissions as an NSPS).
- R&D efforts (ERDA and/or EPA) can be initiated to explore attainable emission and technology levels. Standards would be based on this data base.
- A full-scale standard-setting effort could be initiated, including health studies, control technology evaluation, and economic effects, resulting in nationwide standards.

Selection of the appropriate option depends, of course, on the nature and extent of the problem geothermal plants are expected to present as this energy resource is developed.

C. Recommended Pathway and Associated Information Needs

1. Recommended Pathway

Of the three alternatives available to EPA, GMG concludes that the most feasible approach for both OAQPS and the Division of Stationary Source Enforcement (DSSE) is the establishment of New Source Performance Standards under Clean Air Act Sections 111(b) and (d).

The establishment of ambient air quality standards under Section 108 would require supporting information on the health effects of the pollutant in question. In addition, the designation of a pollutant as a criteria pollutant under Section 108 requires that emissions be controlled from all sources, implying a massive effort to review available control technology from sources other than geothermal power plants.

Action under Section 112 to establish a NESHAP requires information that "the pollutant may cause, or contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness." Section 112 action is not considered likely because available information does not indicate that the emissions from geothermal installations are likely to cause health problems of that magnitude.

The New Source Performance Standard, in contrast, provides an opportunity to control geothermal emissions on an industry-specific basis and thus offers an effective and selective approach to the problem. Table I compares the information needs and timing for each of these regulatory options.

The Emission Standards and Engineering Division, QAQPS, has under consideration several NSPS that are relatable to potential geothermal air pollutants. Although these standards apply to other industries, information gathered in their development may be useful in evaluating whether NSPS should be needed for geothermal applications. The sources, affected facilities, and status (as of November 1, 1976) appear in Table II.

2. Information Needs

Based on the selection of NSPS as the most feasible approach, the path analysis diagram (Figure 3) requires the acquisition of certain information to support eventual NSPS promulgation.

Because the geothermal industry is expected to develop in other states in addition to California, GWG and OAQPS recommend a two-phase R&D program to (1) quantify air pollution emissions and ambient air impact at The Geysers and the Imperial Valley and extend this information to other geothermal sources which may be developed and (2) evaluate air pollution emission control technology for these energy resources.

a. Atmospheric Emissions Studies. The first step would be an extensive literature search followed, if necessary, by source sampling at emission points at The Geysers such as direct contact condensers, gas ejectors, and cooling towers. PG&E reports that an eight-station monitoring network, run by Stanford Research Institute, is determining actual ambient H_2S concentrations. In addition to H_2S measurement, samples should be analyzed for ammonia, mercury, and other organics and trace metals.

The University of California, Lawrence Livermore Laboratory, is currently conducting an extensive baseline study of the Imperial

TABLE I

PRINCIPAL AIR POLLUTION REGULATORY OPTIONS FOR GEOTHERMAL INDUSTRY REGULATION

PRINCIPAL REGULATORY STRATEGY	National Ambient Air Quality Standard	New Source Performance Standard	National Emissions Standard For Hazardous Air Pollutants
CLEAN AIR ACT SECTIONS INVOLVED	108, 109, 110	111(b), (d)	112
KEY FACTORS	• Pollutant oriented • Most difficult to write; requires control of all emission sources: acts via state implementation plans	• Source oriented • Specific to industry • Specific to pollutant (see note 1)	• Pollutant oriented • Health effect involves mortality, serious, irreversible, or incapacitating reversable human illness
LEAD ORGANIZATION FOR IMPLEMENTATION	States	EPA	EPA
INFORMATION REQUIREMENTS	Health and Welfare Information Control Technologies and Costs Effect of emission reductions on air quality	Administrative judgment of contribution to air pollution Information on effectiveness and costs of control techniques	Knowledge or emission level providing ample margin of public safety
TIME REQUIRED TO DEVELOP REGULATION	2-6 years or more; additional time is required to develop and implement State Implementation Plans	Typically 3 years	Typically 2 years (see note 2)

Notes: 1 If pollutant is neither a criteria pollutant under Section 108-110 nor a hazardous pollutant Under Section 112, states must apply similar control to existing sources of the same industrial type, based on best available control technology.

2 Regulatory process is usually expedited due to public pressure to eliminate health hazards.

TABLE II

STATUS OF STANDARDS OF PERFORMANCE WHICH MAY RELATE TO GEOTHERMAL ENERGY

SOURCE	AFFECTED FACILITY	POLLUTANT	OPACITY REGULATION	PROMULGATION DATE	REMARKS
		Standards in Preparation for Proposal			
Sulfur Recovery in Petroleum Refineries	Sulfur recovery plants	SO_2 Sulfides			Proposed 10/4/76
Kraft Pulp Mills	Digesters, lime kiln, recovery furnace, washer, evaporator, strippers, smelt and BLO tanks	Total reduced sulfur (TRS)			Proposed 9/24/76 Typographical Corrections 10/29/76
		Technical Studies (Post Screening)			
Carbon Black Plants	Furnace	Particulate CO H_2S Hydrocarbons	Included		Scheduled Proposal 9/77
Gasification of Fossil Fuels	Coal gasification plants Oil gasification plants	SO_2 & sulfides	Included		Scheduled Proposal 9/77
Natural Gas and Crude Oil Production	Sulfur recovery plants	SO_2 & sulfides			Scheduled Proposal 9/77
Kraft Pulp Mills 111(d)	Existing digesters, lime recovery furnace, washer, evaporator, strippers, smelt and BLO tanks	Total reduced sulfur (TRS)			Scheduled Proposal 1/78 The NSPS will be promulgated about 7/77; 111(d) after this date
Primary Copper, Zinc, and Lead Smelters	Roasters, smelters and converters	Arsenic			Assessment Report complete - Decision to set standards to be made - 4/78

Valley of California and plans to perform further measurements as geothermal development proceeds. Other sites (Appendix B) should be monitored as development occurs.

b. Dose-response and Welfare Data. Because most of the emissions anticipated from geothermal projects are also found in other industrial processes, EPA has specific health and ecological effects information from specific atmospheric concentrations. This should be documented for geothermal applications. Research on health and ecological effects can be limited to characterizing and screening of potential new pollutants at new sites. Such studies need to be done on a case-by-case basis.

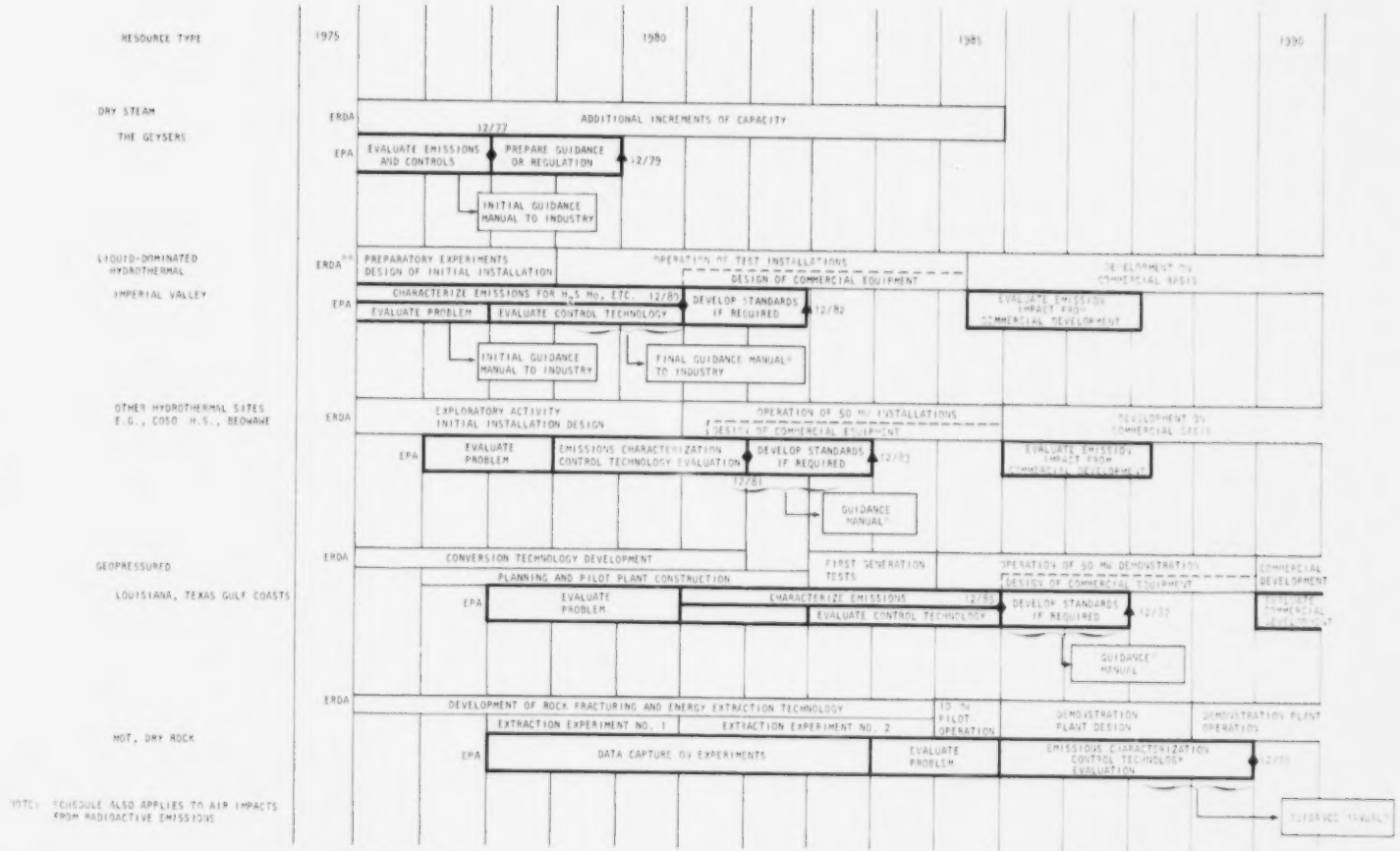
c. Control Methods. Unless the test data indicate otherwise, control method evaluations should concentrate on hydrogen sulfide capture at The Geysers, with evaluations of each new demonstration site on an individual basis. Effectiveness of control systems should be determined from two viewpoints: first, on percent removal efficiency; second, on overall reduction of environmental impact, including whether the steam can continue to be controlled during turbine and well startup, shutdown, and malfunction periods and whether noise, radiation, solid waste, and water pollution problems are diminished or increased by application of the air pollution control system.

If a choice of energy extraction techniques is available, ERDA should be influenced to include the costs of environmental impact and control in its evaluation. That is, the costs associated with environmental problems should be estimated and weighed along with the value of the energy recovered, capital investment, and other factors.

3. Implications of ERDA Plans on Air Pollution Regulatory Decision Schedule

The accelerated pace of geothermal energy development as projected by ERDA reflects the national priority given to development of new energy sources. This priority also merits attention by EPA, and funds to support the necessary studies should be made available, directly and through cooperation with ERDA. GWG recommends a corresponding acceleration of EPA's evaluation of geothermal energy to provide early identification of problem areas, define needed regulation, and indicate where air pollution control is required. As implied by ERDA time lines in Figure 4,* different type of geothermal resources will be developed on

*Figures 4, 6, and 8 are based on: A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices For the Future. Volume 2: Program Implementation, ERDA 76-1, 1976.



*OPTIMUM SCHEDULE FOR DELIVERY IN TIME TO IMPACT DESIGN OF COMMERICAL PLANTS

**INCLUDES BUREAU OF RECLAMATION COMBINED DESALTING AND POWER PRODUCTION UNIT

FIGURE 4
SCHEDULE FACTORS FOR AIR QUALITY ACTIVITY

different schedules. The Geysers, the only known U.S. vapor-dominated resource, is already in operation and additions to its capacity are planned yearly. EPA research is needed now to obtain reliable data on emissions at The Geysers and on control techniques as they are developed, so that the Agency can ensure that projected future capacity increments are handled in a timely, environmentally protective manner.

The press of time is also keen in the case of liquid-dominated hydrothermal resources of the Imperial Valley, where little is known about air quality impacts. The logical approach is to influence the design and demonstration phase and to make a final evaluation of the need to regulate before development reaches the commercial stage. EPA is committed to issue an initial guidance manual to the geothermal industry by July, 1977. This should be followed by a final guidance manual in 1980 or 1981, which will be in time to influence the design of commercial additions to the initial installation at each site. Information for such a manual can be obtained from measurements during the testing and operation of the initial installation. Air pollution control of the later sites will profit from experience gained from the Imperial Valley combined with site-specific emissions measurements made during initial development.

Geopressured and hot dry rock development is expected to quicken about 1980; Figure 4 indicates appropriate EPA R&D action to evaluate air quality problems, to characterize emissions, and to provide guidance to industry.

Figure 4 is based on the information available from ERDA's Program Implementation Plan in 1976. It must be revised annually as geothermal development proceeds. In particular, as ERDA and other organizations commit funds to specific projects for initial installations and loan guaranties the range of proposals will narrow, EPA will be able to direct its activity along the appropriate paths. This revision should be provided to the regulatory offices by ORD.

D. Specific Research Needs

Table III presents a list of research topics generated by OAQPS that GWG recommends be considered as part of an accelerated program of environmental investigation. The portion of EPA's R&D effort on geothermal energy that is related to air pollution should be based on the needs that support the NSPS approach. ORD should define the R&D program in collaboration with OAQPS.

TABLE III

RESEARCH TOPICS IN SUPPORT OF EPA PROGRAM NEEDS: AIR EFFECTS

EMISSIONS CHARACTERIZATION

Study emissions of non-condensable gases and other pollutants

*Characterization of emissions of non-condensable gases
*Characterization of pollutant release from cooling towers, gas ejectors, and other sources
**Develop advanced sensors for atmospheric pollutant measurements

Project emission information for other fields based on resource content

*Develop models to relate emissions to extraction technology and resource type
*Verify models at existing operational sites
*Estimate emission potential of known geothermal resources

Assess local and national environmental impact

*Development of strategies for monitoring systems
*Baseline measurement of ambient air quality at potential resource area
*Monitoring of pollutants at geothermal sites
*Analyze gaseous emissions for known carcinogens
**Characterize pollutant release during exploration

CONTROL TECHNOLOGY EVALUATION AND DEVELOPMENT

Evaluate existing techniques

*Review information sources for available basic systems
*Determine potentially applicable pollution control techniques from other industries
*Evaluate control efficiencies and energy consumption of control techniques

Develop improved control technology or extraction processes

*Identify pollutants presently lacking adequate control technology
**Feasibility studies for advanced concepts in basic systems
**Propose chemical or physical control processes
**Perform laboratory studies of candidate processes

*High priority studies EPA should initiate
**Low priority studies to be considered if time and funds are available

TABLE III (Continued)

RESEARCH PRIORITIES IN SUPPORT OF EPA PROGRAM NEEDS: AIR EFFECTS

Estimate interactions and impacts for control and extraction combinations

*Evaluate energy penalties for control/extraction combinations
*Evaluate costs associated with control/extraction combinations
*Evaluate environmental benefit for control/extraction combinations
*Assess environmental side effects for control/extraction combinations

CONTROL STRATEGY DEVELOPMENT

Estimate level of importance and order of priority of extraction techniques

*Evaluate development schedules and impact of uncontrolled processes
*Develop prioritization of extraction techniques

Develop systematic control strategies

*Develop systematic control strategies for vapor-dominated hydrothermal installations
*Develop systematic control strategies for liquid-dominated hydrothermal installations
**Develop systematic control strategies for geopressured installations
**Develop systematic control strategies for hot dry rock installations

*High priority studies EPA should initiate
**Low priority studies to be considered if time and funds are available

II. WATER QUALITY

A. Problem Evaluation

Assessment of the potential impact of geothermal energy development on water quality is complicated by the fact that the chemistry of geothermal fluids varies significantly from source to source, and the character of the effluent stream will depend on the process used to extract the heat. Geothermal fluids are frequently high in total dissolved solids, and may contain toxic substances such as mercury and arsenic. In addition to the more severe toxicants, other problem effluents include boron, lithium, nitrates, silica, radium, radon, and the waste heat itself, which may contribute to thermal pollution. An important factor in the pollution threat of some toxicants is the ionization state in which they are present. Ionization state is significant in the case of such pollutants as arsenic, which is more toxic as As^{+3} than As^{+5}.

The energy extraction technique employed will also determine the profile of the effluents that must be dealt with. In a flashed steam process some pollutants tend to follow the steam while others remain in solution. If a binary cycle using a secondary working fluid is employed, all the pollutants should remain in the geothermal fluid, but some may tend to precipitate at lower temperatures, complicating disposal efforts.

1. Water Quality Problems in Liquid-Dominated Hydrothermal Sources

Most of the geothermal development to date has been at vapor-dominated resources such as The Geysers and Lardarello, Italy. The quantity of effluent from such sources is low, and reinjection has been used successfully at The Geysers for its disposal. While at least one 50 MW plant is presently planned at Heber, in the Imperial Valley, the largest commercially developed liquid-dominated resource is at Wairakei, New Zealand, where effluents are discharged directly into the Waikato River. At Wairakei, significant environmental effects are suspected from arsenic, mercury, and silica. For comparison, the following information has been developed from Wairakei.

a. Arsenic. The annual discharge of arsenic at Wairakei is approximately 160 metric tons. During periods of average river flow, the concentration has been computed by Axtmann to be about 0.04 ppm, but during periods of drought the stream flow falls to such low levels that arsenic concentrations could reach 0.250 ppm, five times the U.S. standard for drinking water. Clearly, all U.S. sites must be screened for such a serious situation.

b. Mercury. The Wairakei plant is not the only source of mercury in the Waikato River; the river also receives natural geothermal discharges from adjacent areas. Mercury concentrations in trout taken from the river showed an average mercury concentration of approximately 0.5 mg/kg, about the accepted limit for human consumption. Because of the natural sources of mercury discharge, the importance of the geothermal power station discharge is not clear. Again, screening will be necessary for all U.S. sites to avoid initiating a problem or exacerbating an existing situation.

c. Silica. The effluent flow from the Wairakei plant is supersaturated with silica; when the temperature falls the silica precipitates in the amorphous form. The total discharge is large--over 25,000 metric tons per year--and the precipitating silica clogs the discharge channels, requiring its periodic removal. The environmental impact of this discharge on the Waikato river has not been reported, but the disposition of silica and other large volumes of solids must be carefully checked, including fate after reinjection. (In some parts of the Imperial Valley brines contain 250,000 ppm total dissolved solids (TDS).

d. Other Contaminants. In addition to the arsenic, mercury, and silica, Axtmann lists 14 other chemical discharges from the Waraikei plant. (Appendix E) These bear examination in the case of U.S. resources. Also, radioanalysis should be performed on U.S. sources.

2. Overall Situation Assessment

It is evident that uncontrolled discharge of geothermal fluids can have a significant effect on surface water quality. Less clear are the specific threats posed by the individual U.S. sources, or the control measures that may be practical. Reinjection of spent fluids is often cited as a solution to the problem of effluents from liquid-dominated systems. However, as discussed later in the section on ground water protection, reinjection schemes themselves must address a number of problems of engineering and aquifer contamination.

The list of substances found in geothermal fluids (Appendix D) contains a number of elements which appear in Quality Criteria for water that have been developed by the Office of Water Planning and Standards (OWPS). These include ammonia, arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc. Whether the presence of these substances constitutes a problem must be evaluated for each site in the light of the expected discharge concentration and its relation to the flow of the water bodies receiving the discharge.

In summary, geothermal energy poses potential water quality impacts which are likely to depend on the specific details of the source, its extraction technique, and the body of water to which the

pollutant is discharged. These details must be further investigated in order to adequately evaluate both the problem and the appropriate final EPA action.

B. Guidance and Regulatory Actions

1. Guidance

As a minimum level of effort in geothermal water pollution protection, EPA can issue guidance to ERDA, state control agencies, and its own regional offices. Initial activity can comprise the collection of existing data, its evaluation in the light of known water pollution effects, and recommendations for effluent control. EPA should expand this role by collaborating with ERDA to insure that the water data collection and control activities of ERDA reflect EPA and state water pollution planning concerns and to develop the information EPA needs to perform its role. EPA should participate directly in joint water pollution assessment and control efforts with ERDA in order to influence technological choices toward adequate effluent controls and practices.

2. Permits

A geothermal installation that discharges effluents to navigable waters must apply to its state permit-issuing agency or to EPA for a permit under the National Pollutant Discharge Elimination System (NPDES). Under present regulations, the permit-issuing agency must deal with the geothermal plant on an ad hoc basis because no effluent guidelines have been issued for geothermal sources. It must issue a permit or require controls based on experience with similar effluents from other industrial sources. Problems will arise if the geothermal plant effluents differ in character from other industrial sources and if standard control techniques are not applicable to the physical and chemical characteristics of specific geothermal resources and conversion technologies.

Also, under Section 404 of the FWPCA, a permit may be required from the Corps of Engineers prior to the discharge of dredged or fill material into navigable waters of the U.S.

3. Standards Pathways

Under the Federal Water Pollution Control Act Amendments of 1972, PL 92-500, EPA has available four avenues of approach to the control of geothermal impact of water quality:

- o Toxic and Pretreatment Effluent Standards
- o Effluent guidelines

o Control via Section 208 agencies

o Water quality standards

Figure 5 illustrates the decision involved in selecting an approach to geothermal regulation, and Table IV compares the information and the time factors involved.

a. Toxic and Pretreatment Effluent Standards. Regulation could be approached under Section 307, Toxic and Pretreatment Effluent Standards. This path would probably be extremely difficult due to the lengthy hearing process and the burden on EPA to support criteria and to demonstrate levels providing margins of safety.

b. Effluent Guidelines. Effluent guidelines for water quality are analogous to New Source Performance Standards for air quality in that they address point sources of effluents, are industry-specific, and require knowledge of treatment technology and costs as well as effluent characteristics.

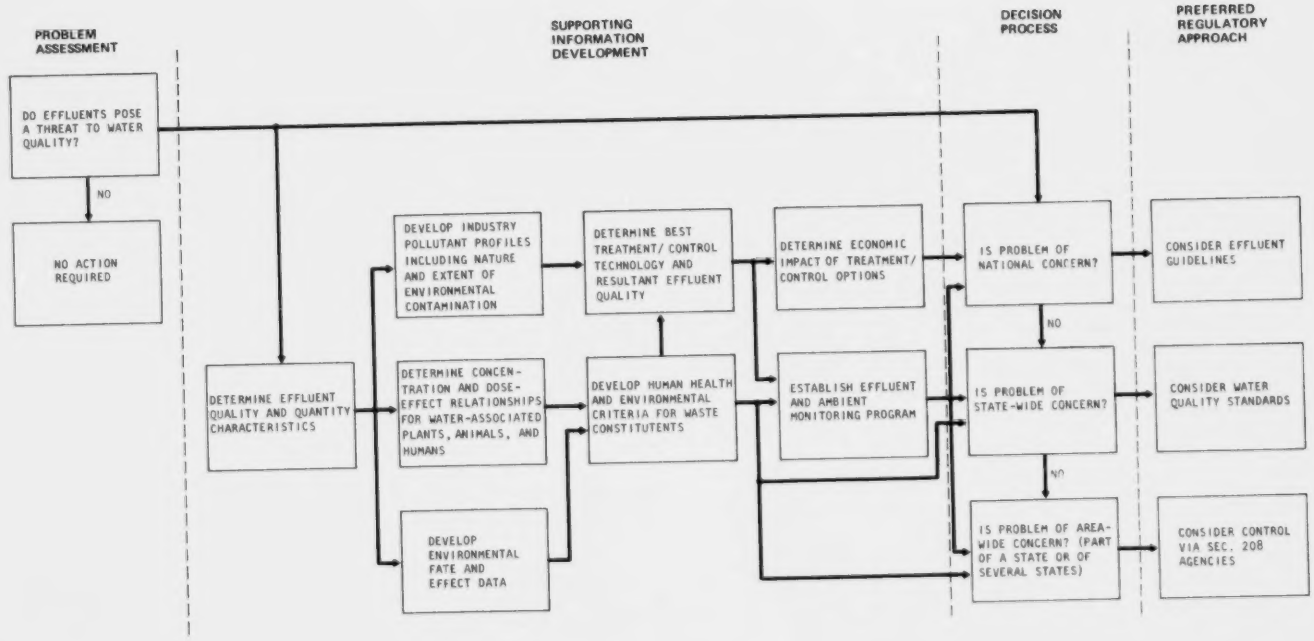
Within the Office of Water Planning and Standards there is no on-going program for the development of effluent guidelines for the geothermal industry. Potential resources for guideline development are heavily committed for the next three years and the placement of any emphasis on the potential geothermal industry problem would require either additional funds and resources, or a reprogramming of existing resources in the face of stringent court mandates, remands, and consent decree actions.

There is a need for a substantial amount of baseline data relating to the problem prior to the development of any effluent guidelines. Control via the avenue of effluent guidelines is possible if data on effluents and control technologies were obtained through cooperative efforts between EPA and ERDA. Once the needed information was in hand, development of effluent guidelines would require between 2 1/2 and 3 1/2 years to accomplish.

c. Control by Section 208 Agencies. A substantial number of Section 208 areawide wastewater management agencies have been designated by state governors during the past several months. Because they are concerned both with the quality of bodies of water and with control of industries that discharge into the water, the 208 agencies represent another way to approach control of geothermal effluents.

Any plan prepared under the 208 process shall include:

> "...the identification of treatment works necessary to meet the anticipated municipal and industrial waste treatment needs of the area over a twenty year period..." 208(b)(2)(A)


PROBLEM ASSESSMENT
SUPPORTING INFORMATION DEVELOPMENT
DECISION PROCESS
PREFERRED REGULATORY APPROACH
DO EFFLUENTS POSE A THREAT TO WATER QUALITY?
NO
NO ACTION REQUIRED
DETERMINE EFFLUENT QUALITY AND QUANTITY CHARACTERISTICS
DEVELOP INDUSTRY POLLUTANT PROFILES INCLUDING NATURE AND EXTENT OF ENVIRONMENTAL CONTAMINATION
DETERMINE CONCENTRATION AND DOSE-EFFECT RELATIONSHIPS FOR WATER-ASSOCIATED PLANTS, ANIMALS, AND HUMANS
DEVELOP ENVIRONMENTAL FATE AND EFFECT DATA
DETERMINE BEST TREATMENT/ CONTROL TECHNOLOGY AND RESULTANT EFFLUENT QUALITY
DEVELOP HUMAN HEALTH AND ENVIRONMENTAL CRITERIA FOR WASTE CONSTITUTENTS
DETERMINE ECONOMIC IMPACT OF TREATMENT/ CONTROL OPTIONS
ESTABLISH EFFLUENT AND AMBIENT MONITORING PROGRAM
IS PROBLEM OF NATIONAL CONCERN?
NO
IS PROBLEM OF STATE-WIDE CONCERN?
NO
IS PROBLEM OF AREA-WIDE CONCERN? (PART OF A STATE OR OF SEVERAL STATES)
CONSIDER EFFLUENT GUIDELINES
CONSIDER WATER QUALITY STANDARDS
CONSIDER CONTROL VIA SEC. 208 AGENCIES

SOURCE: OWPS

FIGURE 5
PREFERRED STANDARDS PATH ANALYSIS FLOW CHART
FOR GEOTHERMAL WATER QUALITY PROTECTION

TABLE IV

PRINCIPAL WATER QUALITY OPTIONS FOR GEOTHERMAL INDUSTRY REGULATION

REGULATORY APPROACH	Water Quality Ambient Standards	Effluent Guidelines	Toxic and Pretreatment Effluent Standards	Control via Section 208 Agencies
FEDERAL WATER POLLUTION CONTROL ACT SECTION	303	301, 302, 304, 306, 402	307	301, 302, 208
KEY FACTORS	State has primacy unless it fails to write an acceptable standard.	Focuses on point sources of effluents; requires considerable EPA effort.	Burden of proof on EPA for establishing criteria, safe levels. Requires preliminary Proposal as a toxic Substance	Relies on state agencies to establish adequate control technology. Guidelines so developed would not have national applicability.
INFORMATION REQUIREMENTS	Health and environmental effects Identification of potential uses for specific body of water	Health and environmental effects Treatment technology and costs	Health effects; Emission level with margin of safety; Treatment technology and costs	Health and environmental effects
TIME REQUIRED TO DEVELOP REGULATION	About 1 year	2½ to 3½ years	Toxic: 2½ - 3½ years Pretreatment: 1-4 years	EPA guidance could be developed in 6 to 18 months.

Consistent with determining treatment needs, 208 agencies could recommend treatment levels for geothermal power plants. If such recommended levels went through a public participation process and eventually became part of an approved 208 plan, those levels would have to be considered by the authority issuing the required National Pollutant Discharge Elimination System permit. A 208 planning agency (areawide or statewide) could be given EPA contract funds to manage a project which would seek to generate effluent limitations for a facility or facilities located in the planning area. Such effluent guidelines would not serve as national guidelines. The guidelines developed by this process could be used in writing permits for the plant(s) in question. EPA guidance to the states under such a process might take a form similar to Waste Load Allocations, and could be expected to require between 6 and 18 months to develop.

d. Water Quality Standards. Some existing regulatory standards are applicable to the industry. Principally these are water quality standards supported by particular water quality criteria that may be identified, and specific state regulations that are applicable to the geothermal industry. EPA's role in the process involves setting water quality criteria that must be met if a given body of water is to sustain a specific type of use. Unless a state has ceded primacy to EPA, the state first determines the beneficial uses applicable to each body of water, then sets water quality standards by consulting the EPA water quality criteria corresponding to those beneficial uses.

e. Related Program Office Activities. The Office of Water Planning and Standards has developed criteria for about 60 water constituents. These criteria, developed pursuant to Section 304(a) of PL 92-500, have been published as Quality Criteria for water. In connection with this effort, the Agency has produced a draft guidance document for the development of Water Quality Standards. If a particular state doesn't adopt the 304(a) criteria in developing its standards, it must justify its decision to EPA.

In addition, the Office has embarked on the development of criteria for an additional 65 constituents based upon existing information, which will be completed by June 1978. Associated with this effort will be the development of effluent guidelines for effluents containing such constituents for 21 industrial categories. ORD is conducting research in water constituent-related areas and such research will be helpful to these regulatory efforts when the results become available.

C. Recommended Pathway and Associated Information Needs

1. Recommended Pathway

First, GWG recommends that, in the near term, existing water quality

criteria and standards be examined for applicability to potential effluent contaminants from geothermal sources.

Second, because geothermal development is projected to take place throughout several states and because it will encompass various distinct conversion technologies and resource types, GWG recommends that EPA adopt a basic, long-term approach aimed at establishing effluent guidelines for the evolving geothermal industry.

The toxic and pretreatment effluent standard approach does not appear to be entirely applicable to geothermal energy at this time, but should be reevaluated as specific types of commercial processes crystallize.

2. Information Needs

The recommended pathway implies the need for supporting information as Figure 5 indicates. GWG and OWPS recommend that the required information be developed through studies in the following areas:

- o Periodically evaluate the nature and extent of the environmental contamination (initially site-specific, later regional)
- o Collect data on effluents from geothermal applications
- o Baseline monitoring at installation sites
- o Assessment of the environmental impact of various energy extraction and conversion techniques
- o Reactions of wastewater pollutants
- o Synergistic effects of toxicants
- o Potential disposition of geothermal wastes, including direct discharge, solar evaporation, and subsurface reinjection

As geothermal technology evolves, the effluent guideline approach for the geothermal industry will also require information on:

- o Methods of cooling waste water prior to surface disposal
- o Treatment technologies and their associated costs.

The recommended method of gathering this information would be through ERDA's experimental and initial installation activities. EPA technical personnel should be part of such research in an advisory or coordinating capacity.

3. Implication of ERDA Plans on Water Quality Regulatory Decision Schedule

EPA concern with geothermal energy water quality protection is greatest in the case of liquid-dominated hydrothermal sites, because they combine early projected development with a potential for large volumes of effluent brine. Liquid effluents represent a relatively small fraction of mass flow at The Geysers, and effluent reinjection has been successfully demonstrated for this vapor-dominated system.

The earliest anticipated development of liquid-dominated sources is expected at Heber, in the Imperial Valley of California (Figure 6).

EPA plans to issue a preliminary guidance manual in mid-1977 to provide advance information on environmental protection problems. If environmental information is to be furnished in a timely manner for commercial development of the Imperial Valley sites, a final guidance manual must be available in 1980. Information on which to base the manual should be obtained from effluent measurements at existing installations.

Other groups of hydrothermal sites are expected to see initial operation in 1980 and 1981, with commercial expansion following the initial operation by five years. EPA guidance for these sites should be issued in 1981 and 1982, and will probably require site-specific effluent data that can be obtained from the initial equipment.

Geopressured and hot dry rock installations are not expected to see commercial development prior to 1990. EPA should plan now to follow the progress of these types and to obtain data to provide water quality protection guidance by 1985 or 1986.

It should be recognized that this 1976 development scenario can be expected to change, and should be periodically revised. As ERDA and the industry commit themselves to loan guaranties and specific projects, EPA will be better able to focus its information gathering and its guidance.

D. Specific Research Needs

Table V presents a tentative list of research topics generated by OWPS that GWG recommends to satisfy the information requirements involved in geothermal environmental protection. The portion of EPA's R&D effort on geothermal energy that is related to water pollution should be based on these needs, that generally support the effluent guidelines approach. ORD should define the R&D program after collaboration with OWPS.

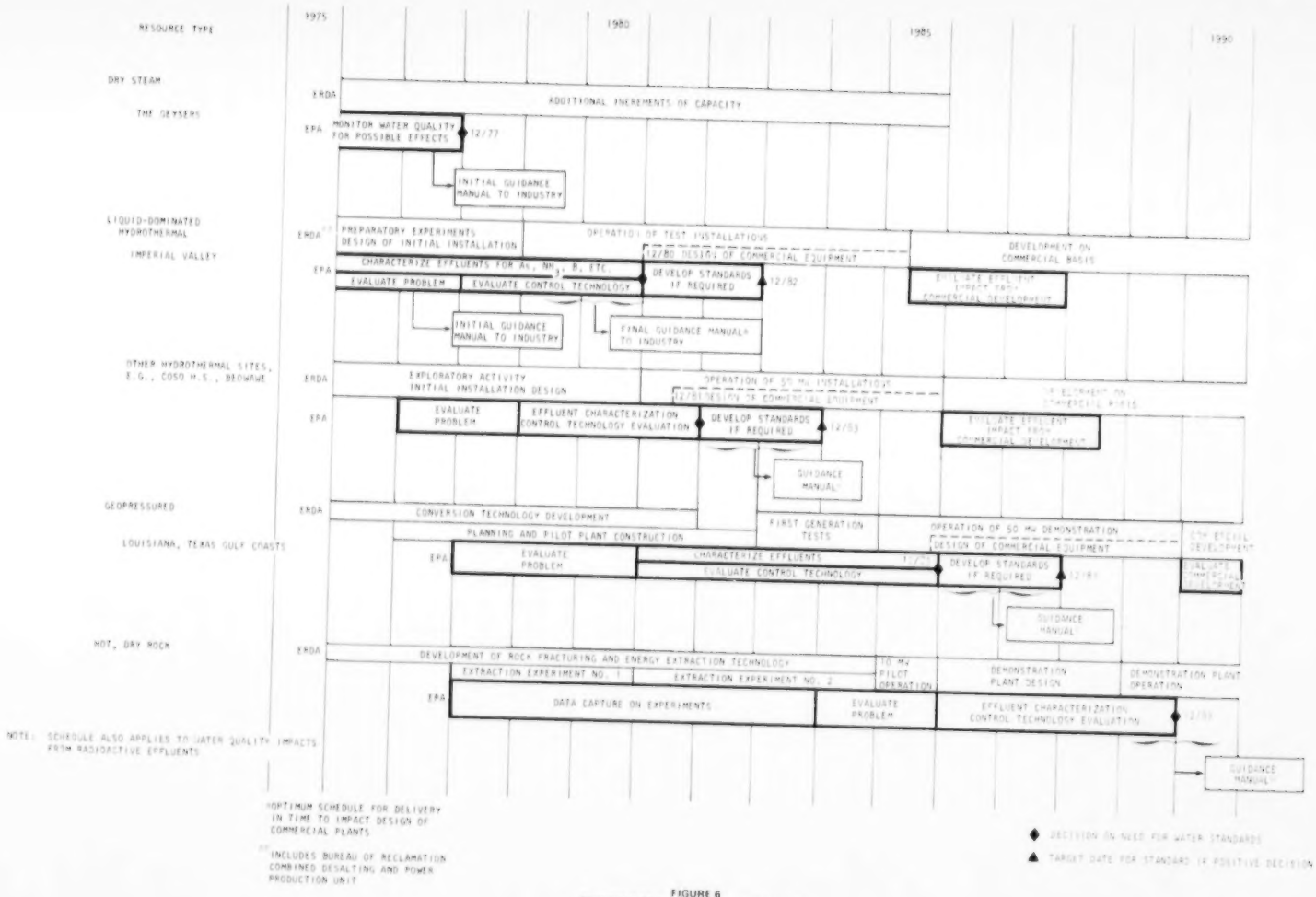


FIGURE 6
SCHEDULE FOR WATER QUALITY ACTIVITY

TABLE V

RESEARCH PRIORITIES IN SUPPORT OF EPA PROGRAM NEEDS:
WATER QUALITY

CHARACTERIZATION, MEASUREMENT, AND MONITORING

*Baseline Measurement of Ambient Water Quality at Potential Resource Area
*Characterization of Liquid Effluents, Including Cooling Tower Drift and Waste Water
*Water Quality Monitoring at Geothermal Sites (H_2S Trace Element)
*Characterize Toxic Agents

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

*Study Movement/Fate of Geothermal Effluents (Brines, Gases, Cooling Towers)
*Evaluate Ability of Soil to Absorb and Neutralize Water Pollution
*Hydrological Characterization of Geothermal Resource Areas
*Study/Model Changes in Surface Water Due to Geothermal Operations
*Assess Annual/Seasonal Variations in Flows
*Study Effects of Geologic Disturbances on Water Flow

HEALTH EFFECTS

**Determine Dose Effects in Animals
**Determine Levels of Human Exposure
**Determine Health Effects of Toxicant Combinations

ECOLOGICAL EFFECTS

*Review Toxicological Literature (Geothermal Pollutants)
*Conduct Baseline Inventory and Monitoring Studies
*Literature Review of Hazardous Effluents From Cooling Systems
*Identify Transfer and Fate of Cooling Systems Pollution in Freshwater Ecosystems
**Marine and Estuarine Dose-Response Studies (Cooling Systems Research)
**Freshwater Dose-Response Studies
**Effects of Cooling Systems on Coastal Ecosystems

*High priority studies EPA should initiate
**Low priority studies to be considered if time and funds are available.

POLLUTANT CONTROL TECHNOLOGY

*Establish Waste Products and Side Effects of Geothermal Energy Systems
*Evaluate Existing Geothermal Energy Pollution Control Techniques
*Determine Potentially Applicable Pollution Control Techniques From Other Industries
*Determine Hazards and Disposal Problems Associated with Waste Products and Side Effects
*Compare Input Stream Treatment With Output Stream Treatment For Each Pollutant
*Evaluate Control Efficiencies and Energy Consumption of Control Side Effects
*Identify Pollutants Presently Lacking Adequate Control Technology
*Propose Candidate Chemical or Physical Control Processes
**Determine Feasibility of Geothermal Materials Recovery
**Perform Laboratory Studies of Candidate Techniques
**Conduct Pilot Installation and Evaluation of Selected Control Techniques
**Develop Systematic Control Strategies for Vapor-Dominated Hydrothermal Installations
**Develop Systematic Control Strategies for Liquid-Dominated Hydrothermal Installations
**Develop Systematic Control Strategies for Geopressured Installations
**Develop Systematic Control Strategies for Hot Dry Rock Installations
**Assess Local Impacts of Geothermal Field Development

*High priority studies EPA should initiate
**Low priority studies to be considered if time and funds are available.

III. GROUND WATER PROTECTION

A. Problem Evaluation

1. Aquifer Contamination

The problem of minimizing the impact of geothermal energy development on drinking water supplies involves questions not only of geothermal chemistry, but also of geology, the composition of the rock formations involved, and standards for the drilling and completion of wells. Drinking water aquifers are frequently protected by impervious strata from contamination by surface water or by other subsurface aquifers. Geothermal exploration and development activity can open paths between aquifers creating a pollution hazard that is independent of the composition of the geothermal brine itself.

It is evident, then, that efforts to protect ground water must consider the direct problem of leakage of geothermal fluids from wells or disposal ponds into other aquifers. Equally important is the problem of aquifer contamination during well drilling, or from poor casing or cementing practices that may allow fluids to flow from one aquifer to another. When an exploratory well is abandoned, it can create a similar hazard by providing a vertical channel through several impermeable strata, in which leaks may later create interconnecting paths.

Reinjection of geothermal fluids, frequently mentioned as an answer to subsidence and to prevent surface water contamination, can also provide opportunities for aquifer contamination through leaks and other problems. Indeed, reinjection may not be feasible in all cases because dissolved solids may precipitate at the lower effluent temperature or may react with minerals in the receiving formation, plugging up the pore spaces and preventing further disposal. Problems of corrosion and scaling in the reinjection equipment must also be solved before reinjection can be considered a practical pollution control technique. These problems of compatibility between reinjected fluids and the disposal formation and of effect on the reinjection equipment can be expected to differ significantly among geothermal sites, and may require solution on an individual basis. Fluid characterization and reinjection compatibility should be assessed together at specific sites.

2. Subsidence

An important topic related to geothermal extraction and injection is the possibility of induced subsidence. Subsidence frequently occurs where large quantities of fluid are withdrawn from a geologic formation, removing the support from the overlying strata.

It may be a critical consideration in the Gulf Coast area, where a large geopressured geothermal resources that are rich in methane exist in conjunction with land areas that are only a few feet above sea level.

3. Seismicity

Seismicity presents a problem because geothermal resources are commonly found in areas of natural seismic activity, implying difficulty in distinguishing the effects of geothermal development as well as raising questions involving possible interaction effects. It has been argued that reinjection could stimulate seismic effects by lubricating fault areas, and this effect has been reported in connection with the disposal of hazardous wastes in Colorado. On the other hand, withdrawal of fluids could conceivably cause a fault to lock, causing tectonic pressures to build up and produce a large earthquake in place of a natural series of minor shocks. The ambiguity in this issue is emphasized by the fact that fluid injection has been proposed as a technique for reducing the severity of earthquakes through controlled lubrication of geologic faults.

4. Overall Situation Assessment

In the cases of aquifer contamination and subsidence, the physical mechanism of the environmental impact is well understood, and what is required is specific information on the engineering of appropriate drilling standards and other control measures to prevent adverse effects. The topic of seismicity requires significantly more information about the basic phenomenon and whether it is likely to present a significant environmental problem, or even be a serious obstacle to geothermal development.

B. Guidance and Regulatory Actions

1. Guidance

Because much of the authority over ground water is reserved to the states, guidance should be an important part of any EPA program of ground water protection. The EPA can play an active role in gathering and evaluating data on ground water problems and control measures. Some of this guidance can be general in nature, but should be supplemented by assistance in site-specific problems of geology, fluid chemistry, and extraction and development technique.

2. Permits

Although ground water contamination can occur either from extraction or injection, direct EPA regulatory authority extends only to injection activities, either reinjection of hydrothermal fluids

or direct injection into hot dry rock. Regulation of pollution incidental to extraction wells would have to be covered under state regulations for such wells. As discussed below, EPA is in the process of issuing injection regulations (40 CFR Part 146) as part of its State Underground Injection Control Program.

3. Regulatory Pathways

Under present practices EPA has two avenues of regulatory control over subsurface injection; these are compared in Table VI, and the implied decision process appears in Figure 7. When the state-administered regulations of 40 CFR Part 146 take effect, an applicant for a reinjection permit will be required under subpart C to furnish geologic and fluid data regarding the proposed operation and design information showing compliance with the protective requirements.

A second opportunity for control exists where reinjection involves storage or treatment of subsurface fluids. Where a geothermal operation reinjects subsurface fluids, the state has the option to regulate the reinjection under 40 CFR 146. If the state has declined to accept primacy on geothermal reinjection, the EPA region would require a permit under the Underground Injection Control (UIC) program. Where the wastes are stored or treated prior to reinjection, then the application would be handled under the National Pollution Discharge Elimination System (NPDES). When an application for an NPDES permit is received the EPA regional office may elect to apply 40 CFR 146 or Administrator's Decision No. 5. The choice is unlikely to affect the operation, since the two documents are very close, the difference being that some information that is mandatory under Administrator's Decision No. 5 is at the option of the regulatory agency under 40 CFR 146.

C. Recommended Pathway and Associated Information Needs

1. Recommended Pathway

The GWG concludes that the present EPA authority vested in OWS is adequate to support a posture of early guidance to and minimal regulation of geothermal energy. The injection regulations of 40 CFR Part 146 can serve to control geothermal reinjection operations, and studies can be performed to develop information regarding specific problems of reinjection. In view of the accelerated development foreseen for geothermal energy, ERDA's cooperation should be enlisted to derive such information.

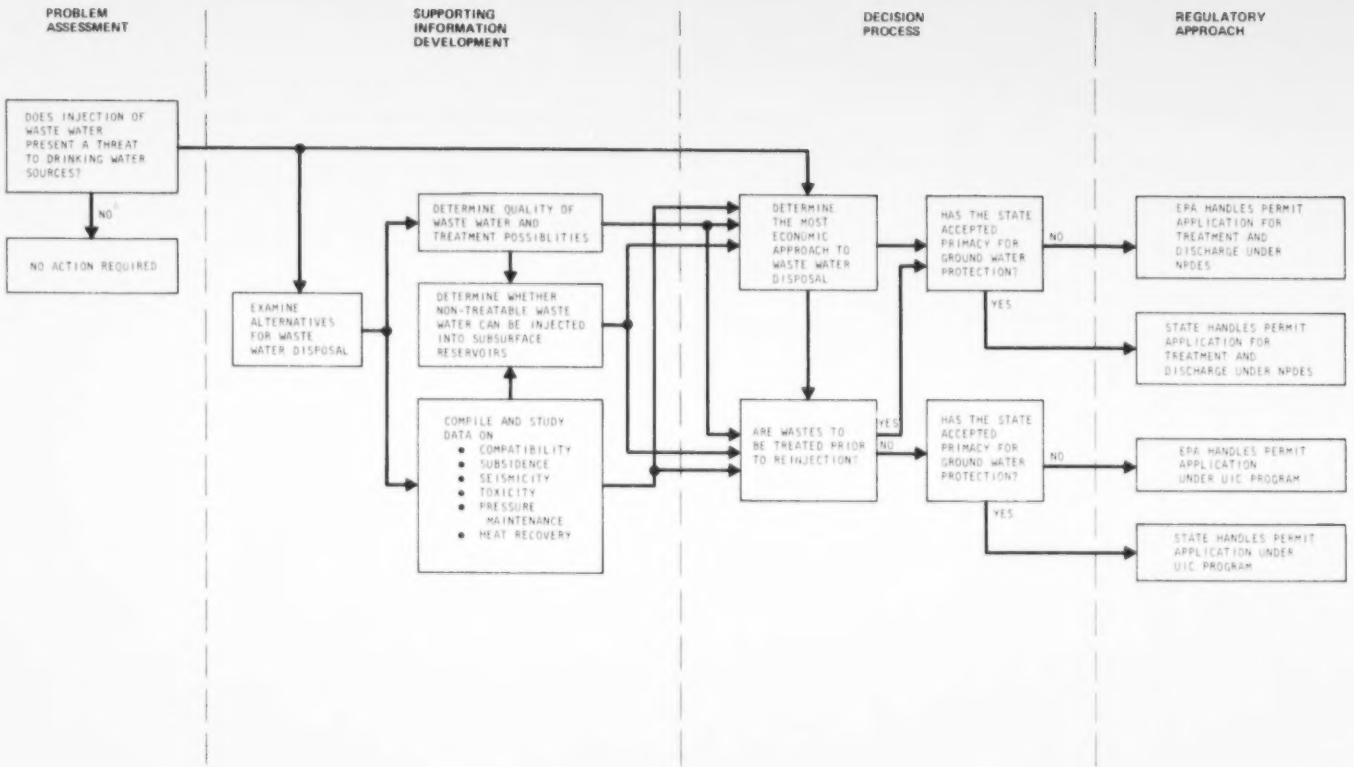
2. Information Needs

Based on the fact that existing groundwater reinjection regulations are at least minimally adequate for geothermal development, the path

TABLE VI

PRINCIPAL GROUND WATER PROTECTION OPTIONS FOR GEOTHERMAL INDUSTRY REGULATION

	INJECTION OPERATIONS		EXTRACTION OPERATIONS
REGULATORY APPROACH	Permit Issuance under Administrator's Decision No. 5	Permit Issuance under 40 CFR 146	No specific Federal Authority Exists; must be addressed under state authority over extraction wells.
KEY FACTORS	Requires mandatory submission of data regarding proposed well design, operation, relation to other wells and geologic structures, etc.	Similar data required, but some items are at the option of the permit issuing authority.	Fluid extraction may affect drinking water aquifers, or may cause subsidence in certain geologic structures.
INFORMATION REQUIREMENTS	Application of existing regulations requires knowledge of compatibility of injected fluids with formations and possibilities for pretreatment.		
TIME REQUIRED TO DEVELOP INFORMATION	Eighteen months to determine problem boundaries and point out areas of specific concern. Some required information is site-specific and will need determination on an individual basis as part of permit issuance.		


PROBLEM ASSESSMENT
SUPPORTING INFORMATION DEVELOPMENT
DECISION PROCESS
REGULATORY APPROACH
DOES INJECTION OF WASTE WATER PRESENT A THREAT TO DRINKING WATER SOURCES?
NO*
NO ACTION REQUIRED
EXAMINE ALTERNATIVES FOR WASTE WATER DISPOSAL
DETERMINE QUALITY OF WASTE WATER AND TREATMENT POSSIBLITIES
DETERMINE WHETHER NON-TREATABLE WASTE WATER CAN BE INJECTED INTO SUBSURFACE RESERVOIRS
COMPILE AND STUDY DATA ON
COMPATIBILITY
SUBSIDENCE
SEISMICITY
TOXICITY
PRESSURE MAINTENANCE
HEAT RECOVERY
DETERMINE THE MOST ECONOMIC APPROACH TO WASTE WATER DISPOSAL
ARE WASTES TO BE TREATED PRIOR TO REINJECTION?
YES
NO
HAS THE STATE ACCEPTED PRIMACY FOR GROUND WATER PROTECTION?
NO
YES
EPA HANDLES PERMIT APPLICATION FOR TREATMENT AND DISCHARGE UNDER NPDES
STATE HANDLES PERMIT APPLICATION FOR TREATMENT AND DISCHARGE UNDER NPDES
HAS THE STATE ACCEPTED PRIMACY FOR GROUND WATER PROTECTION?
NO
YES
EPA HANDLES PERMIT APPLICATION UNDER UIC PROGRAM
STATE HANDLES PERMIT APPLICATION UNDER UIC PROGRAM

*EITHER NO WATER SUPPLY INVOLVED OR NO THREAT

FIGURE 7
REGULATORY PATH ANALYSIS FLOW CHART FOR GEOTHERMAL WASTE WATER

analysis diagram (Figure 7) requires the development of certain information to support regulation in specific cases. In order to determine the feasibility and environmental protection requirements of reinjection practices. GWG and OWS recommend that information be developed in three basic areas:

- Lithology of the strata in geothermal areas
- Chemistry of the injected and formation fluids
- Possibilities for preinjection treatment

These areas should be investigated through a number of related efforts:

- Collection and tabulation of fluids data from geothermal resource areas
- Baseline monitoring of ground water at installation sites
- Laboratory studies of the compatibility of geothermal fluids and injection formations based on actual samples from the area under development
- Laboratory studies of possible preinjection treatment of geothermal effluents to ensure their compatibility with the receiving formations
- EPA participation with ERDA in three or four initial experiments and installations, to develop knowledge of the problems and hazards involved
- Verification studies to provide independent confirmation of the effect of control techniques and construction practices
- Cooperation with the Geological Survey in research on the seismic and subsidence hazards of geothermal operations

3. Implications of ERDA Plans to Ground Water Protection Regulatory Decision Schedule

The problems of ground water protection, subsidence control, and feasibility of reinjection are interrelated, and require solution if the anticipated growth of the geothermal industry is to be achieved. It is believed that EPA has in hand sufficient information involving the mechanics of reinjection to control the problem of ground water pollution. In contrast, reinjection to prevent subsidence involves the questions of fluid formation compatibility already discussed. In

order to issue guidelines for subsidence control, EPA needs information on the compatibility issues. Laboratory studies to define the basic problems and indicate critical factors could be completed in 2 years. Joint efforts with ERDA, verification studies, and USGS-related subsidence and seismic efforts are also essential, but schedules would depend on the cooperation of the other agencies and the availability of suitable experimental projects.

As in the case of water quality protection, ground water protection is likely to be most heavily concerned with liquid-dominated hydrothermal sites in the near future (Figure 8). Reinjection has been successfully demonstrated at The Geysers, and EPA attention can be limited to ground water quality monitoring to discover problems.

The Imperial Valley hydrothermal sites will need guidance at an early date because reinjection is likely to play a major role. The initial EPA guidance manual is planned for mid-1977. It seems reasonable for EPA to plan for full environmental control by the time commercial expansion begins. This implies that a final package should be written by about 1980 to be in time to affect the design of commercial additions to the initial installation. Such guidance could rest on effluent and compatibility data collected at the initial installation. EPA guidance for subsequent hydrothermal sites will probably be able to draw on much of the Imperial Valley experience, with supplementary data collected from each site as initial installations are built.

The question of subsidence is prominent in development of geopressured sites. Here the scheduled activity is less immediate, and EPA should aim for guidance to be issued about 1985.

The scenario presented here rests on the best information available in 1976. It should be given periodic revision as ERDA and the geothermal industry commit themselves to specific projects. Such commitment will narrow the range of possibilities confronting EPA and allow EPA in turn to address its efforts to the most productive and necessary activities.

D. Specific Research Needs

Table VII lists specific research projects identified by OWS to develop the information discussed above. The topics have been ranked in three categories:

1. Need exists to verify ongoing or completed high-priority studies by others

2. High priority studies EPA should initiate

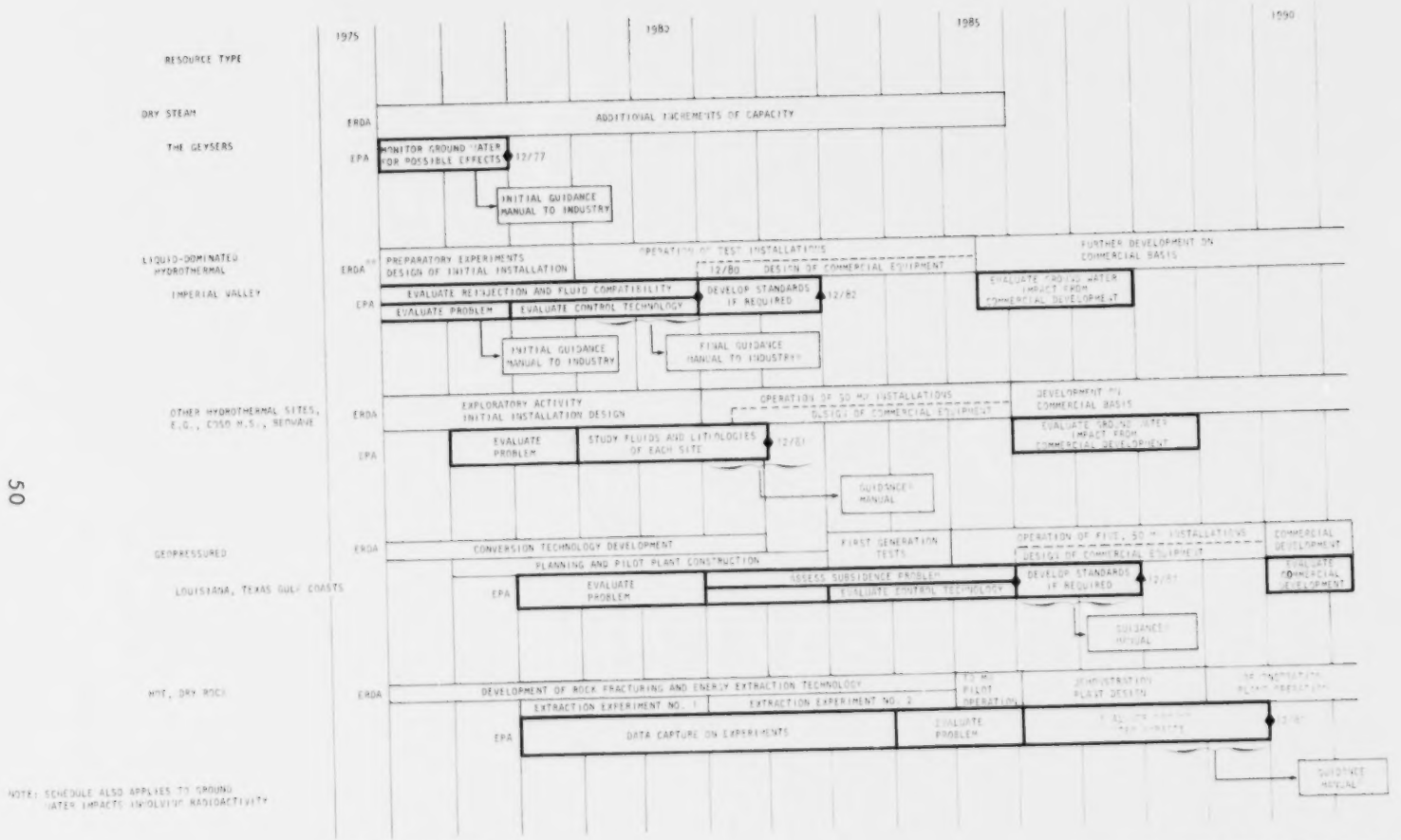


FIGURE 8
SCHEDULE FACTORS FOR GROUND WATER PROTECTION

TABLE VII

RESEARCH PRIORITIES IN SUPPORT OF EPA PROGRAM NEEDS:
GROUND WATER PROTECTION

CHARACTERIZATION, MEASUREMENT, AND MONITORING

*Baseline Measurement of Ambient Ground Water Quality at Potential Resource Area
*Characterization of Liquid Effluents, Including Cooling Tower Drift and Waste Water
**Characterize Toxic Agents

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

*Study Compatibility of Geothermal Brines With Associated Geologic Formations
*Assess Subsidence in Geothermal Fields
*Assess Reinjection Practices--Induced Seismicity
*Study Aquifer Disturbance by Geothermal Operations
***Studies of Physical/Chemical Properties of Soils, Rocky Mountains and Northern Great Plains
**Study Subsidence Potential of Various Geologic Formations
**Study Seismic Potential of Various Geologic Formations
***Study Relationship of Aquifers to Geologic Formations
**Hydrological Characterization of Geothermal Resource Areas
*Study Modification of Thermal Structure of Ground Water at Geothermal Sites
*Physical/Chemical Studies of Reaction/Movement of Geothermal Brines
**Study and Model Changes in Surface/Ground Water Due to Geothermal Operations
**Study Flow Pathways of Water in Various Geologic Formations
***Study Effects of Geologic Disturbances on Water Flow
***Study Chemical/Exchange Processes in Various Materials
***Assess Impact of Extraction of Geopressured Resources (Gulf Coast)

CONTROL TECHNOLOGY

*Evaluate and Develop Methods for Pre-injection Treatment to Assure Compatibility

---

*Need to verify ongoing or completed high-priority studies by others
**High-priority studies EPA should initiate
***Low-priority studies to be considered if time and funds are available

3. Low priority studies EPA may wish to perform if time and funds are available

Early contacts with ERDA indicate many of the important topics have been studied by others or are addressed by ongoing studies in related problem areas. What is needed in this case is to obtain and evaluate the data and results to assure that what has been done is in fact accurate and complete. The data should then be reviewed to assure that all factors concerning ground water protection have been covered and if not, to make recommendations for additional work that may be considered necessary. The portion of EPA's R&D effort on geothermal energy that is related to groundwater pollution should be based on these needs that support existing regulations. ORD should define such a program after collaboration with OWS.

IV. RADIATION

A. Problem Evaluation

The radiation hazards associated with geothermal energy are a form of Technologically Enhanced Natural Radioactivity (TENR). Geothermal energy production does not create radioactive isotopes, but it may produce increased or even hazardous levels of exposure by concentrating a naturally radioactive element or by bringing it to the surface of the earth.

1. Radium and Radon

Radium and Radon, the two principal radioactive elements identified with geothermal development, occur naturally and may be released through geothermal extraction or may be concentrated in the atmosphere in hothouse or hydroponic applications. The biological impact results from the subsequent radioactive decay products or short half-life radon daughters, or from the release of radium in the effluent.

2. Impact of Pollution Control Technology

Pollution control technology for other pollutants may be a factor in determining the radiation hazard, since the control devices installed to remove a chemical pollutant may be effective in removing radioactive elements as well. Viewed another way, the control device may concentrate radioactive products in its sludge or other output, creating a radiation problem in its storage and removal.

Radioactivity also must be considered in disposal of solid waste, as discussed in a later section.

3. Overall Situation Assessment

The elements involved in radioactivity are well-known, as are the effects of radiation. The principal unknown factor in geothermal energy is the magnitude of individual and population doses which might be encountered from specific applications. Impacts may be significant chiefly for persons whose place of work or residence is near a source of geothermally-enhanced radiation. Occupational studies are in order at initial installations.

B. Guidance and Regulatory Actions

Since naturally radioactive materials may be present as solid waste, liquid effluents, or gases, radiation presents an environmental problem that cuts across the traditional EPA program office

boundaries. EPA's authority includes an advisory role to other Federal agencies in addition to its own regulatory function.

1. Guidance to Other Federal Agencies

EPA acts in an advisory capacity to other Federal agencies in writing their own internal regulations regarding environmental radiation impacts. EPA has not revised the general numerical limits originally set by the Federal Radiation Council for individual doses, which are not sufficiently restrictive, because radiation exposure can usually be made much lower without significant economic penalties. In addition to the numerical bounds, EPA provides qualitative guidance, to ensure that adequate controls are provided. Because there is no known radiation level at which zero impact exists, qualitative guidance has been to require that radiation doses be kept as far as practicable below the numerical limits. Practicability is judged by a cost/benefit analysis which addresses the effectiveness of the control technique, and includes the impact of the anticipated radiation level as a cost.

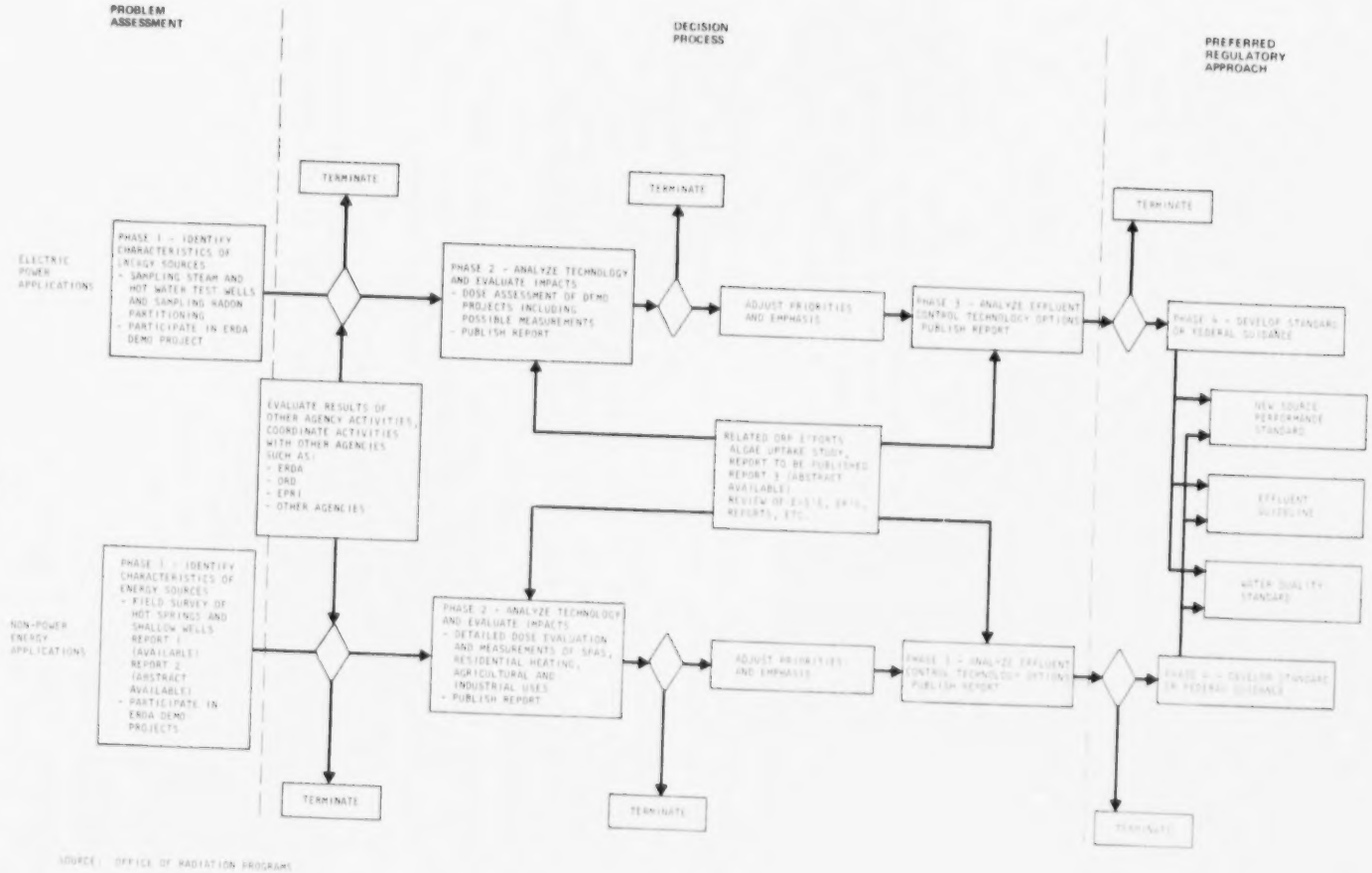
2. Standards Pathways

The Criteria and Standards Division of the Office of Radiation Programs has determined that the Standards for Protection Against Radiation (10 CFR 20), that form the basis for activities regulated by the Nuclear Regulatory Commission, do not apply to geothermal energy. This is because 10 CFR 20 is limited to the component materials and by-products of nuclear fission, under the Atomic Energy Act of 1954. EPA does have authority to regulate radiation aspects of geothermal energy under the Clean Air Act, Federal Water Pollution Control Act and the Safe Drinking Water Act. The options for such actions are the same for radiation as for chemical problems, as discussed in the preceding sections on air quality, water quality and groundwater protection.

C. Recommended Pathway and Associated Information Needs

1. Recommended Pathway

The need and form of any required regulation involving radiation will rest on the specifics of the problem. EPA's Office of Radiation Programs (ORP) has under way a study to determine the scope of the impact and whether further work in this area is required. ORP's efforts concerning the radiological aspects of geothermal energy fall logically into three groups: (1) electrical power applications, (2) non-electrical power applications, and (3) related studies. The plan for this evaluation appears in Figure 9.


PROBLEM ASSESSMENT
DECISION PROCESS
PREFERRED REGULATORY APPROACH
ELECTRIC POWER APPLICATIONS
NON-POWER ENERGY APPLICATIONS
PHASE 1 - IDENTIFY CHARACTERISTICS OF ENERGY SOURCES
- SAMPLING STEAM AND HOT WATER TEST WELLS AND SAMPLING RADON PARTITIONING
- PARTICIPATE IN ERDA DEMO PROJECT
PHASE 1 - IDENTIFY CHARACTERISTICS OF ENERGY SOURCES
- FIELD SURVEY OF HOT SPRINGS AND SHALLOW WELLS REPORT 1 (AVAILABLE)
REPORT 2 (ABSTRACT AVAILABLE)
- PARTICIPATE IN ERDA DEMO PROJECTS
EVALUATE RESULTS OF OTHER AGENCY ACTIVITIES, COORDINATE ACTIVITIES WITH OTHER AGENCIES SUCH AS:
- ERDA
- ORD
- EPRI
- OTHER AGENCIES
TERMINATE
TERMINATE
TERMINATE
TERMINATE
TERMINATE
PHASE 2 - ANALYZE TECHNOLOGY AND EVALUATE IMPACTS
- DOSE ASSESSMENT OF DEMO PROJECTS INCLUDING POSSIBLE MEASUREMENTS
- PUBLISH REPORT
PHASE 2 - ANALYZE TECHNOLOGY AND EVALUATE IMPACTS
- DETAILED DOSE EVALUATION AND MEASUREMENTS OF SPAS, RESIDENTIAL HEATING, AGRICULTURAL AND INDUSTRIAL USES
- PUBLISH REPORT
ADJUST PRIORITIES AND EMPHASIS
ADJUST PRIORITIES AND EMPHASIS
RELATED ORP EFFORTS
- ALGAE UPTAKE STUDY, REPORT TO BE PUBLISHED
- REPORT 3 (ABSTRACT AVAILABLE)
- REVIEW OF EXISTING ERDA REPORTS, ETC.
PHASE 3 - ANALYZE EFFLUENT CONTROL TECHNOLOGY OPTIONS PUBLISH REPORT
PHASE 3 - ANALYZE EFFLUENT CONTROL TECHNOLOGY OPTIONS PUBLISH REPORT
PHASE 4 - DEVELOP STANDARD OR FEDERAL GUIDANCE
NEW SOURCE PERFORMANCE STANDARD
EFFLUENT GUIDELINE
WATER QUALITY STANDARD
PHASE 4 - DEVELOP STANDARD OR FEDERAL GUIDANCE

SOURCE: OFFICE OF RADIATION PROGRAMS

FIGURE 9
PLAN FOR RADIATION HAZARD EVALUATION OF GEOTHERMAL ENERGY SOURCES

For non-electric applications, ORP expects to complete by the end of FY 76 the first phase of the program--the characterization of geothermal sources, their radiological effluents, and preliminary analyses of the environmental impacts.

In early FY 77, ORP will make a decision concerning the level of effort to be applied on geothermal energy tasks for the future. This will be based on theoretical calculations of potential environmental radiological impacts. If warranted by the scoping dose assessment of non-power geothermal hot springs and shallow wells, ORP will progress into the second stage of making on-site dose measurements. For the electrical power applications, the level of effort will depend on three developments: (1) the timely completion of a power plant prototype project by ERDA, (2) the results of the preliminary field surveys at the Imperial Valley prototype demonstration project and (3) availability of contract funds for ORP from other EPA groups. If the decision is made to continue the effort in geothermal power applications, ORP will make detailed evaluations of the environmental effects of ERDA's power plant prototype through field measurements and paper studies. Based on the results of the power plant prototype study, ORP will decide whether to proceed with further work on geothermal power sources, which would lead to standards development.

It should be noted that ERDA has identified five sources of geothermal energy: hydrothermal convective, geopressured, hot dry rock, volcanic, and normal gradient. Only one of these sources, hydrothermal convective, has been commercially demonstrated and only one commercially developed resource, The Geysers, exists in the U.S. ORP's efforts have been concentrated on this source; however ORP plans to evaluate other future sources in a fashion similar to the present plans for hydrothermal convective.

The power applications efforts will be centered around ERDA's developmental program plans. The initial plant, and the only near-term effort, began test operation in the Imperial Valley, California, geothermal fields in June 1976.

The non-power uses of geothermal energy include space and water heating, irrigation for agricultural purposes, industrial process heat applications, and development of health spas. Each application will be evaluated initially for the potential of contributing significant doses. Since the basic dose problems will arise from the radon, the geothermal efforts will draw on the ongoing ORP radon modeling work associated with the uranium mining and milling analyses.

2. Information Needs

As with other impacts, the most urgent requirement in the radiation area is for a continuing program of research and cooperation with

ERDA to assess the nature and extent of the problem. In the area of radiation, such a study should focus on the potential individual and population doses that might be encountered from the various applications of geothermal energy. This study would in turn be used to indicate the need for further investigations. These investigations would address the radiation release points in various industrial applications of geothermal energy. For each release point the source terms (release rates) would be evaluated, together with the capabilities for source term control.

a. Technology for Radon and Radon Daughter Measurement. Current techniques need to be addressed for measuring radon and radon daughters in geothermal fluid under conditions of high steam/water pressures, temperatures, and humidities. Development of rapid field techniques will be an important step in assessing doses to individuals from applications of geothermal fluids. Some initial work is in progress and should be evaluated and included in planning EPA's own efforts.

b. Radium Uptake by Crops. The emphasis of this study will be on hothouse and hydroponic applications of geothermal fluids. Radionuclides in crops from such enterprises (as well as potentially elevated radon concentrations in hothouses) affect small, but different, populations than electrical geothermal applications. The populations must be identified and their risk evaluated.

c. Radionuclide Enrichment Effected by Resource Recovery. Additional study is necessary to determine if the products of the mineral recovery processes associated with geothermal developments are enriched in radionuclides as a result of the process.

d. Radon in Water. Increased understanding of radon steam/water partitioning and radon solubility in the temperature and pressure ranges characteristic of geothermal fluids would have application to several areas of interest. An initial, somewhat theoretical, approach would provide an estimate of the quantities of radon expected from geothermal reservoirs. Knowledge of radon behavior in water has application to other studies such as indoor radon concentrations from drinking water supplies.

e. Additional Studies. In addition to the foregoing areas, it is likely that several additional areas of study, or of sharper definition of those stated above, will become apparent from the dose assessment study. A need is foreseen for research in environmental measurements of waste effluents (air and liquid) from geothermal applications of the natural radioactivity in the environs of the prototype facilities.

V. SOLID WASTE

A. Problem Evaluation

Solid waste disposal does not at this time appear to present as great a problem with geothermal energy as it does in many other energy technologies, but some problems of solid waste disposal associated with liquid-dominated hydrothermal operation will merit EPA's attention.

1. Sludge Disposal

The sludge that accumulates at the bottom of cooling towers contains a number of the elements found in the source wells. At the Geysers, this sludge is currently disposed of by burial in areas known to have a stable geologic structure and negligible potential for ground water contamination, but such sites are not plentiful and the process is costly. Other sources of problem waste can accumulate in holding ponds receiving liquid wastes and from devices installed to control air or water pollution.

2. Radioactivity Associated With Solid Waste

Radioactivity must also be considered in addressing solid waste impacts. As discussed in the section on radiation, the accumulation from environmental control processes may result in pollutants reaching problem levels of concentration. Any materials recovery from solid waste would require review because of natural radioactivity. Use of land where wastes have been buried must consider the possibility of radon emission.

3. Drilling Muds

The muds used in drilling operations often contain toxic substances, and may be considered as solid waste produced in the processes of exploration and development.

4. Overall Situation Assessment

The solid waste resulting from cooling tower operations, emission control, materials recovery, or exploration may present difficult problems. The existence, nature, and extent of the problems will depend on the specifics of the resource, type of geothermal development, and technological details. This question should be addressed on a site-by-site basis.

B. Guidance and Regulatory Actions

Collection and disposal of solid wastes continues to be primarily the function of State, regional and local agencies. However, the national scope of the solid waste problem necessitates Federal action through financial and technical assistance and leadership. The Resource Conservation and Recovery Act of 1976 (Public Law 94-580) assigns to EPA and the States authority and responsibility for control and management of the disposal of solid wastes, especially hazardous wastes, in the following areas.

- Issuance of guidelines and regulations for the management and disposal of solid wastes and especially hazardous wastes including:

  a. Defining the characteristics of various solid wastes and identifying and listing hazardous wastes to be controlled;

  b. Developing standards for the generation, transport, storage, treatment, and disposal of hazardous wastes and guidelines for the management of other wastes, and

  c. Promulgating criteria which define acceptable methods of disposition in sanitary landfills, and which define prohibited methods such as disposal in open dumps.

- Assistance to States and other jurisdictions in complying with the Act by:

  a. Providing advisory Resource Recovery and Conservation Panel teams of specialists for consultation;

  b. Promulgating guidelines for State management plans along with statutory approval or disapproval;

  c. Providing study grants and financial assistance to operators of disposal facilities,

  d. Coordinating, collecting and disseminating related information; and

  e. Determine training needs for operating disposal facilities

- Conducting a National Research and Development program to:

  a. Develop and demonstrate waste management technology;

  b. Conduct studies in specifically enumerated waste management areas; and

  c. Develop operating criteria for available disposal technologies.

- Integrating administration and enforcement of the act with related statutes (Clean Air Act, Federal Water Pollution Control Act).

- Conducting miscellaneous activities in:

  a. Evaluation of the potential for employment loss or shifts;

  b. Reporting to the Congress; and

  c. Instituting Federal suit to restrain imminent hazards.

C. Recommended Pathways and Associated Information Needs

1. Recommended Pathways

GWG recommends that EPA institute close coordination with ERDA in the development of geothermal resources which will be accompanied by the production of geothermal wastes requiring disposal. This close coordination should extend to State and local agencies in geothermal resource areas.

2. Information Needs

Because the impact of solid waste disposal depends on the site and extraction and conversion technologies involved, it will be necessary to establish site-specific evaluations of solid waste production including the wastes produced from pollution control devices.

VI. NOISE

A. Problem Evaluation

The noise produced in connection with geothermal development activity may constitute a significant environmental impact in certain cases. Noise emission can arise from a number of phases of geothermal exploration such as drilling operations and the release of steam during well-bore cleaning.

After a plant is in operation, noise is produced by the generating machinery cooling towers, transformers, and other devices. During periods of maintenance, the steam wells are shut down and, when generation resumes, the wells and collection lines must be purged of condensed water and allowed to reach thermal equilibrium before steam is admitted to the generator. During this process, steam is exhausted directly to the atmosphere, a process that is very noisy if suitable mufflers are not applied. Very loud noises can cause temporary or permanent loss of hearing, especially in an occupational setting, but lower levels can also affect public welfare, as in the case of a vacation site or residential area whose attractiveness is decreased by noise from a nearby geothermal installation.

1. Overall Situation Assessment

Acoustic noise as an environmental problem may show up as a nuisance affecting recreational land use or may have adverse effects on some forms of wildlife. Either effect is likely to occur only in special circumstances peculiar to individual sites.

B. Guidance and Regulatory Actions

EPA does not have any direct authority over noise generated by geothermal installations. The agency's authority in noise abatement and control is limited to a few closely defined areas including transportation noise as it occurs in airports, railroad switching yards, and highways. EPA also has the authority to prescribe regulations for products designated as major noise sources, where noise emission standards are feasible and where the product falls into one of the following categories: construction equipment, transportation equipment, any motor or engine, electrical or electronic equipment.

However, under Section 14 (Research, Technical Assistance and Public Information) of the Noise Control Act of 1972, EPA is authorized to complement, as necessary, the noise research programs of other Federal agencies on the effects, measurement and control of noise. In addition, Section 4(c)(1) authorizes EPA to coordinate the programs of all Federal agencies relating to noise research and noise control.

1. Guidance

If noise becomes an environmental problem in geothermal development, EPA could collect data and issue guidance to state and local noise control authorities.

C. Recommended Pathway and Associated Information Needs

GWG recommends that EPA keep abreast of noise production associated with geothermal projects so that it can recognize potentially significant impacts and issue appropriate guidance. This activity may involve coordination with ERDA and review of data by EPA, supplemented by specific noise measurement activity where the need is evident. Early guidance can influence ERDA's internal environmental and safety regulations, which are applicable to all projects using ERDA funds.

VII. LAND USE IMPACT

A. Problem Evaluation

The development of a geothermal resource involves use of substantial land areas. In addition to the generating station, which may occupy about 51 hectares (ha) for a power plant of 1000 MW electrical output (MWe), geothermal development involves the drilling of numerous wells and installation of a system of pipelines to collect the fluid. Based on experience at The Geysers, a geothermal power plant of 1000 MWe may require from 90 to 150 wells. The spacing involves about 24 hectares of land per well, or between 2000 and 3600 hectares for such installation. Since geothermal steam and hot water cannot be transported economically over long distances, the energy must be used or converted into electrical power near the source. Thus, the impact of a geothermal source is principally on the development site itself. This is in contrast to most other energy sources, which may require considerable land areas for mining, fuel processing, and transportation in addition to the actual use or electrical generation site.

1. Impacts of Geothermal Development

As noted above, the bulk of the affected area is involved with the geothermal wells and collection lines. The wells require heavy machinery for their drilling and completion, which in turn implies a need for construction or improvement of access roads to support the activity. Depending on soil conditions in the area, the roads may require some form of artificial surface or soil stabilization.

The drill pad required for each well may range from one half to one hectare, and must be leveled and cleared of vegetation. The drilling operation includes a sump for the containment of waste fluids and drill cuttings, which must be lined or sealed to provide a basin. Its size depends on the expected depth of the hole; the surface area may range from less than a hundred to several thousand square meters, with a depth of one to three meters or more. Steam or hot water lines are run above ground, and include large loops placed at intervals to allow for thermal expansion and contraction. Construction of these lines involves ecological disturbance to wild areas, and their existence may impede the use of farm machinery in agricultural areas.

Local riparian and other customary land rights may be infringed by the intrusion of the structure and its attendant lines. Odor and acoustic noise, both discussed in preceding sections, may reduce the value of resort, recreational, or residential land use if not adequately controlled.

2. Compatibility with Other Land Uses

Although the development of a geothermal resource may prevent some land uses, other uses may continue in reasonable harmony. The site at Lardarello, Italy is also used for farms, vineyards, and orchards. Prior to the development of The Geysers, the land was used for hunting and fishing. This use has continued, along with approximately 360 hectares recently leased for cattle grazing. The impact of geothermal development on land use can be expected to present different problems for each site, which must be resolved with the cooperation of the developer, property owners, and state and local government agencies.

3. Overall Situation Assessment

The question of land use impact tends to be highly site-specific for any energy generating plant, because of the disparity of other uses to which a given site may be put. Geothermal energy presents an opportunity in this area to blend energy extraction with other beneficial uses of the land.

B. Guidance and Regulatory Actions

The Environmental Protection Agency has no specific authority in the area of land use control at the present time.

C. Recommended Pathway and Associated Information Needs

GWG recommends that EPA keep abreast of the land-use impacts at existing geothermal installations in the U.S. and abroad, as well as the potential conflicts involved with planned ERDA projects. This activity will generate a data base for EPA guidance to its regional offices and to ERDA, which may be influenced toward adopting environmentally protective site selection criteria and land use practices in geothermal demonstration installations where extensive commercial development might follow.

SECTION 5

SUMMARY

I. BACKGROUND

The Federal Geothermal Advisory Council (GAC), on which EPA is represented, has requested that EPA develop standards or guidelines for the emerging geothermal energy industry.

Because geothermal energy is only one of a series of new energy technologies and because EPA's regulatory program priorities and resources are largely committed to addressing existing industrial problems (including conventional energy-related pollution sources), an internal EPA working group was formed to recommend an approach to answer GAC's request. It was agreed that the Office of Research and Development should chair the working group because of its lead role in the Interagency Energy/Environment R&D Program, which is aimed at developing information on the environmental effects of the emerging energy technologies.

II. GEOTHERMAL WORKING GROUP CONCLUSIONS AND RECOMMENDATIONS

A. Problem Assessment and Conclusions of the Geothermal Working Group

While the evolutionary phase of the geothermal energy industry does not immediately present a significant environmental threat, environmental issues relating to geothermal energy are expected to arise in several locales throughout the Western U.S. within the next 5 to 10 years. The diverse nature of geothermal resources demands that the severity of the local threat to health and the environment be examined on a case by case basis. Therefore, the GWG has reached the following conclusions.

1. Environmental Standards

- In view of the state of knowledge of geothermal resources and the status of and ERDA's plans for conversion technology development, and given the evolutionary nature of geothermal development, the immediate setting of standards for the industry by EPA is unnecessary.

- However, in view of the federal plans for and commitment to energy development, EPA as a whole should plan now to be in a position to set standards and to regulate the evolving industry as events demand.

2. Emission and Effluent Information

- Continually updated information on emission and effluent profiles and environmental implications of geothermal energy extraction and conversion technologies is (and will continue to be) needed from ERDA and industry during development, but especially in advance of key decision points in ERDA's choice of specific processes.

- Therefore, EPA must actively consult and participate with ERDA and industry as development proceeds.

3. Multimedia Pollutant Information

- Much environmental information on geothermal resources is available from various federal and state agencies, but it is not comprehensive when compared with EPA's regulatory needs.

- Information on geothermal resource sites is needed from these sources (e.g., ERDA, USGS, states) as early as possible in advance of development, with additional data to be gathered by EPA as development demands.

B. EPA Authorities and Capabilities

- No specific EPA standards, criteria or regulations exist for the geothermal industry as such.

- New Source Review in its present form cannot regulate expected emissions from geothermal plants.

- NPDES may be capable of regulating some geothermally related contaminants, but not in a comprehensive manner at present.

- Environmental Impact Review provides an important mechanism for assessing the overall effects of a specified project, but it is not designed to impact the evolution and development of the technology and resource type selection which lead to the EIS for specific projects or to the EAR for programmatic documents.

- Existing NAAQS and NESHAPS cannot effectively control geothermally related air pollutants.

- Existing water quality criteria may be applicable in regulating some geothermal effluents. This approach should be examined in detail at once to determine its breadth of effectiveness.

- o Existing injection regulations appear to be generally adequate for regulation of geothermal development, but this must be re-evaluated periodically in the light of evolving technology.

C. Strategy and Recommendations

The basic strategy recommended for adoption by EPA is to influence the eventual (commercialization phase) choices of geothermal resource/technology combinations to be made by ERDA and industry by continually participating in the RD&D phase of the national geothermal program as it evolves, through the establishment of a formal consulting role with ERDA's geothermal development office.

It is recommended, therefore, that EPA take the following steps:

a) Establish a formal Memorandum of Understanding (MOU) with ERDA's Division of Geothermal Energy defining the role of EPA in DGE's program.

b) Embark on an interim program of periodic dissemination of formal guidance to ERDA and industry which is geared to developmental progress.

c) Issue, as requested by GAC, an initial Guidance Manual based on present knowledge in July 1977.

d) Adopt a coherent, EPA-wide regulatory mission-oriented timetable and associated R&D program wherein comprehensive regulatory decision milestones are geared to the pace of industry development and the R&D information required to make such decisions is developed in the course of actual technology development. The expected ERDA and EPA milestones in this development are summarized in Table VIII and for OAWM and OWHM in Figures 4, 6, and 8.

e) The need for special standards should be evaluated for certain specific or unique problems, such as that of hydrogen sulfide at The Geysers.

f) The decision to promulgate standards and criteria for the geothermal industry should be evaluated well in advance of commercialization in order to be useful in preliminary environmental review processes. (See Figures 4, 6, and 8.)

g) A comprehensive, long-range EPA R&D program should be developed in accordance with the needs herein noted.

h) A standing internal EPA staff group should be maintained to coordinate development of the guidance manuals.

i) The recommended approach for geothermal air regulation is through evaluation of the need for and development of NSPS keyed to events in geothermal development.

j) The recommended approach for geothermal water quality regulation is through development of effluent guidelines keyed to events in geothermal development.

TABLE VIII

KEY MILESTONES IN PROPOSED ERDA/EPA GEOTHERMAL ACTIVITY

These EPA Agency milestones are keyed to ERDA/industry events in the development of various geothermal resource types. The dates given are best estimates as of 1976. They must be updated by ORD each year to reflect changes in the ERDA Geothermal RD&D Program and in industrial initiatives. The relative relationship of EPA events to ERDA/industry events must be preserved or changed through intra-EPA review to ensure a comprehensive and temporally coherent EPA response.

YEAR (1976 ESTIMATE)	ERDA/INDUSTRY EVENTS	EPA EVENTS (Parentheses Indicate ERDA/Industry Events Determining Schedule of EPA Events and Future EPA Events for which Earlier EPA Events Prepare)
1976		
• DRY STEAM (GEYSERS)	1. Continue additional increments of capacity at The Geysers, CA	1. Begin evaluating emissions, effluents, and ground water impact at The Geysers (ERDA event 1, EPA event 3)
• LIQUID DOMINATED HYDROTHERMAL	2. Continue equipment tests for desalting-power production units* (Imperial Valley, Mesa, CA)	
	3. Continue development and testing of high temperature, high salinity thermal test loop (flash to binary cycle). (Imperial Valley, Niland, CA)	
	4. Begin development and testing of high temperature, high salinity direct flash test rig. (Imperial Valley)	2. Begin evaluating air, water, and ground water problems for Imperial Valley hydrothermal sites. (ERDA events 2-6; EPA event 4)
	5. Begin development of high temperature, moderate salinity test facility. (Imperial Valley, East Mesa, CA)	
	6. Continue planning of liquid-dominated hydrothermal demonstration plant number 1. (Imperial Valley, Heber, CA)	
	7. Continue volcanic hydrothermal evaluation studies. (Hawaii)	
• GEOPRESSURED	8. Continue production and completion technology development studies for geopressured resources (Louisiana and Texas)	
	9. Continue conversion technology development studies for geopressured resources	
• HOT DRY ROCK	10. Continue hot dry rock energy extraction technology studies	
	11. Continue hot dry rock heat extraction experiments and development of test facilities (Jemez Mt., NM)	
1977		
• DRY STEAM (GEYSERS)	12. Industry initiates continued expansion planned annually through 1985 (Pending resolution of local environmental questions)	3. Decision on need for EPA standards applicable to The Geysers (ERDA event 12, EPA event 9)

*Bureau of Reclamation activity

TABLE VIII (CONTINUED)

KEY MILESTONES IN PROPOSED ERDA/EPA GEOTHERMAL ACTIVITY

YEAR (1976 ESTIMATE)	ERDA/INDUSTRY EVENTS	EPA EVENTS (Parentheses Indicate ERDA/Industry Events Determining Schedule of EPA Events and Future EPA Events for which Earlier EPA Events Prepare)
• LIQUID-DOMINATED HYDROTHERMAL	13. Begin development and testing of high temperature, high salinity test facility. (Imperial Valley)	4. Issue initial guidance manual for air, water, and ground water effects of Geysers, Imperial Valley and Raft River hydrothermal sites; characterize emissions, effluents, and ground water effects (ERDA events 1-6, 12, 13, 14) (July, 1977)
	14. Decision to construct moderate temperature resource thermal loop (Raft River, Idaho)	
	15. Begin planning liquid-dominated hydrothermal demonstration plant number 2	5. Evaluate environmental problems for other liquid-dominated hydrothermal sites (e.g. Renwave, Roosevelt H.S., Coso H.S.) (ERDA event 15, EPA event 10)
• GEOPRESSURED	16. Begin planning of geopressured resource pilot plant	
1978		
• LIQUID-DOMINATED HYDROTHERMAL	17. Begin construction of 500,000 GPD-500 kW desalting power production pilot plant* (Imperial Valley)	6. Begin control technology evaluation for Imperial Valley and Raft River hydrothermal sites (ERDA events 2-6, 13, 14, 17, 18, 22; EPA events 11,12)
	18. Decision to construct high temperature, high salinity pilot plant (Imperial Valley)	
• GEOPRESSURED	19. Decision to construct geopressured resource test facility/pilot plant	7. Begin to evaluate environmental problems of geopressured resources (ERDA events 8, 9, 16, 19, 36; EPA events 19, 25)
• HOT DRY ROCK	20. Begin impermeable hot, dry rock energy extraction test	8. Begin data capture on hot, dry rock thermal extraction experiment (ERDA event 20, EPA event 20)
1979		
• DRY STEAM (GEYSERS)	21. Industry expansion phase underway	9. Target date for EPA standards for dry steam, if necessary from EPA decision event 3
• LIQUID-DOMINATED HYDROTHERMAL	22. Begin construction of liquid-dominated hydrothermal demonstration plants number 1 and number 2	10. Characterize emissions and evaluate control technology at initial installations at other hydrothermal sites (ERDA events 15, possibly 7; EPA event 13)
	23. Begin operation of 500,000 GPD-500 kW desalting-power production pilot plant* (Mesa, Imperial Valley, CA)	
	24. Decision to convert moderate temperature thermal loop to pilot plant (Raft River, Idaho)	
	25. Decision to construct test facility and thermal loop for volcanic resources	
• HOT DRY ROCK	26. Begin planning and construction of hot dry rock pilot plant	

*Bureau of Reclamation

TABLE VIII (CONTINUED)

KEY MILESTONES IN PROPOSED ERDA/EPA GEOTHERMAL ACTIVITY

YEAR (1976 ESTIMATE)	ERDA/INDUSTRY EVENTS	EPA EVENTS (Parentheses Indicate ERDA/Industry Events Determining Schedule of EPA Events and Future EPA Events for which Earlier EPA Events Prepare)
1980		
• LIQUID-DOMINATED HYDROTHERMAL	27. Begin construction of CRBSCP--Title I** desalting-power production plant*	
	28. Begin construction of Mesa anomaly desalting-power production plants*	11. Decision on need for EPA standards applicable to Imperial Valley and Raft River sites (ERDA events 2-6, 13, 17, 18, 23, 29, 30, 31, 32, 33; EPA events 12, 16)
	29. Begin operation of high temperature, moderate salinity test facility in Imperial Valley	
	30. Begin operation of high temperature, high salinity pilot plant in Imperial Valley	12. Issue final guidance manual for Imperial Valley and Raft River hydrothermal sites (ERDA events 27-30, 32)
1981		
• LIQUID-DOMINATED HYDROTHERMAL	31. Begin operation of moderate temperature pilot plant (Raft River, Idaho)	13. Decision on need for EPA standards applicable to other hydrothermal sites (ERDA events 15, 22, 33; EPA event 18)
	32. Begin operation of demonstration plant number 1 (Imperial Valley)	
	33. Begin operation of demonstration plant number 2	
• HOT DRY ROCK	34. Begin permeable hot, dry rock extraction test	
• GEOPRESSURED		14. Begin emissions characterization at geopressured test sites (ERDA events 8, 9, 19, 36; EPA events 19, 22)
1982		
• LIQUID-DOMINATED HYDROTHERMAL	35. Begin operation of volcanic hydrothermal resource test facility	15. Issue guidance manual for other hydrothermal sites (ERDA events 15, 21, 33; EPA event 24)
		16. Target date for EPA standards for Imperial Valley and Raft River hydrothermal sites if required by EPA event 11 (ERDA events 31 and 32)
• GEOPRESSURED	36. Begin operation of geopressured resource pilot plant	17. Geopressured emissions characterization (ERDA event 36 ; EPA event 19)
1983		
• LIQUID-DOMINATED HYDROTHERMAL	37. Initial commercialization of other hydrothermal sites	18. Target date for EPA standards for other hydrothermal sites if required by EPA event 13 (ERDA event 33)
• GEOPRESSURED	38. Geopressured pilot plant operation continues	19. Evaluate control technology for geopressured test installations (ERDA events 36, 38)
1984		
• HOT DRY ROCK	39. Begin planning and construction of hot, dry rock demonstration plant.	20. Evaluate environmental problems of hot, dry rock resources (ERDA event 39, EPA events 28, 29)

*Bureau of Reclamation activity

**Colorado River Basin Salinity Control Project

TABLE VIII (CONCLUDED)

KEY MILESTONES IN PROPOSED ERDA/EPA GEOTHERMAL ACTIVITY

YEAR (1976 ESTIMATE)	ERDA/INDUSTRY EVENTS	EPA EVENTS (Parentheses Indicate ERDA/Industry Events Determining Schedule of EPA Events and Future EPA Events for which Earlier EPA Events Prepare)
1985		
• LIQUID-DOMINATED HYDROTHERMAL	40. Begin operation of CRBSCP--Title 1 desalting-power production plant*	21. Assess impacts of commercial-scale development of Imperial Valley sites
• GEOPRESSURED	41. Geopressured demonstration (1985)	22. Decision on need for EPA standards applicable to geopressured development (ERDA event 36; EPA events 25-27)
• HOT DRY ROCK	42. Begin operation of hot, dry rock pilot plant	23. Environmental data capture (ERDA event 42; EPA event 29)
1986 – 2000		
• LIQUID-DOMINATED HYDROTHERMAL	43. Widespread hydrothermal commercialization (After 1985)	24. Assess impacts of commercial-scale development of other hydrothermal sites (1986 - 1990)
• GEOPRESSURED	44. Geopressured commercial plant (1986 - 1991)	25. Issue guidance manual for geopressured development (1986)
		26. Target date for EPA standards for geopressured (1987 - 1990)
		27. Assess impacts of commercial-scale development of geopressured resources (1990)
• HOT, DRY ROCK	45. Begin operation of hot, dry rock demonstration plant (Date uncertain)	28. Begin emissions characterization and control technology evaluation for hot, dry rock resources (Approximately 1986) (ERDA event 42; EPA event 29)
		29. Issue guidance manual for hot dry rock resources; evaluate need for EPA regulation (1989) (ERDA event 45)

*Bureau of Reclamation activity

**Colorado River Basin Salinity Control Project

APPENDIX A
GEOTHERMAL WORKING GROUP MEMBERS

Member	Organization	Telephone Number
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Albert E. Fry	Office of Planning and Management	(202) 755-2811
David Shaver	Office of Planning and Management	(202) 755-2893
Robert P. Hartley	Industrial Environmental Research Laboratory-Cincinnati	(513) 684-4335
Kenneth Mackenthun	Office of Water Planning and Standards	(202) 755-0100
Gary McCutchen	Office of Air Quality Planning and Standards	(919) 688-8146 Ext. 271
Neill Thomasson	Office of Radiation Programs	(202) 755-4860
David Duncan	Office of Radiation Programs	(202) 755-0920
	Participant from Other Offices	
George Stevens	Stationary Source Enforcement Division	(202) 755-0103
Eugene Wyszpolski	Office of Noise Control Programs	(202) 557-8292
Mark Mercer	Office of Solid Waste Programs	(202) 755-9170

APPENDIX B

GEOTHERMAL RESOURCE AREAS

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Source: Comptroller General of the United States, "Problems in Identifying, Developing and Using Geothermal Resources," March 6, 1975.

FIGURE B-1
KNOWN AND POTENTIAL GEOTHERMAL RESOURCE AREAS IN THE UNITED STATES

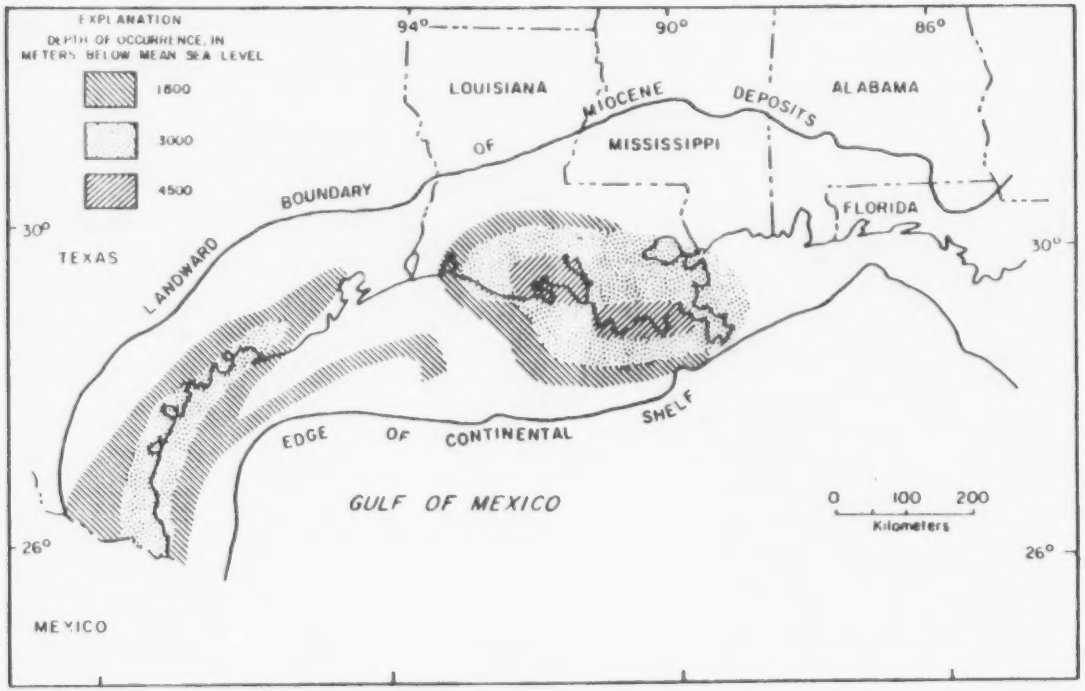

FIGURE B-2
AREAS OF POTENTIAL GEOPRESSURED RESOURCES IN THE U.S.

LEGEND

- ✱ Developed Geothermal Field
- ● Areas Undergoing Evaluation for Development
- ▲ Deep Exploratory Drill Hole, 1968-75
- ■ Drilling as Part of Research Program
- ○ Utilization of Low-Enthalpy Fluids

Source: James B. Koenig, *et al*, "Exploration and Development of Geothermal Resources in the United States," Second United Nations Symposium for the Development and Utilization of Geothermal Resources, San Francisco, May 1975.

FIGURE B-3
GEOTHERMAL EXPLORATION IN THE UNITED STATES

APPENDIX C

STATUS OF H_2S CONTROL TECHNOLOGY AT THE GEYSERS

PG&E has recently begun full-scale source control of 110 MW Unit No. 11. H_2S is combined with oxygen in the presence of an iron catalyst to yield water and sulfur. The sulfur is iron-contaminated and unsalable, creating a solid waste problem. An estimated 90 percent efficiency reduces H_2S emissions to 0.5 pounds per MWh. Newer power plants use surface rather than direct contact condensers, so that most (90 percent) of the H_2S comes out in the noncondensable gases. This permits use of the Stretford process to remove H_2S, a system which, if efforts are made to minimize H_2S escape at the cooling tower, results in overall efficiencies as high as 98 percent.

Both control systems treat gases after the steam leaves the turbine. If the turbine is shut down, the H_2S-laden steam is vented directly to the atmosphere. Because it requires 24 hours to shut down a well and additional time to reopen one and clear out pebbles and rocks which can be picked up by the steam and damage the turbine, it is impractical to shut down the well during brief periods of turbine down-time.

Treating steam prior to the turbine may prove feasible. This would permit control during shutdown. ERDA-sponsored laboratory studies are exploring the feasibility of using regenerated copper or nickel to capture the H_2S as a sulfate.

APPENDIX D

CHEMICAL ELEMENTS AND COMPOUNDS REPORTED IN ANALYSES OF GEOTHERMAL FLUIDS

Aluminum
Ammonia
Argon
Arsenic
Bicarbonate/carbonate
Barium
Boron
Bromide
Cadmium
Calcium
Carbon Dioxide
Carbon Monoxide
Cesium
Chloride
Chromium
Copper
Ethane
Fluoride
Hydrogen
Hydrogen Sulfide
Iodide
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Methane
Nitrogen
Nitrous oxides
Nitrate
Oxides of sulfur
Phosphate
Potassium
Rubidium
Silica
Silver
Sodium
Strontium
Sulfate
Sulfide
Zinc

Source: J. G. Douglas, et al., Geothermal Water and Gas: Collected Methods for Sampling and Analysis, Battelle Pacific Northwest Laboratories, Richland, Washington, August 1972.

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APPENDIX E

ANNUAL CHEMICAL DISCHARGES TO THE WAIKATO RIVER FROM THE WAIRAKEI GEOTHERMAL POWER PLANT

Constituent	Approximate Annual Discharge in Metric Tons per Year
Boron	1,100
Lithium	520
Sodium	48,000
Potassium	7,600
Rubidium	120
Cesium	100
Magnesium	0.19
Calcium	680
Fluorine	310
Chlorine	83,000
Bromine	220
Iodine	19
Ammonia	6
Sulfate	960
*Arsenic	160
*Mercury	0.006
Silica	25,000

*Appears on list of 65 chemicals named in consent degree between environmental groups and EPA.

Source: R. C. Axtmann, "Environmental Impact of a Geothermal Power Plant", Science, v 187, n 4179, 7 March 1975

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APPENDIX F

EIS REVIEW

The Environmental Protection Agency participates in the environmental impact statement (EIS) process in a number of ways:

- o EPA may provide guidance and information to other Federal agencies at the pre-EIS stage of a major Federal action. Under certain circumstances, EPA may assist in the preparation of another agency's EIS, but such a contribution must be clearly identified as a product of EPA.

- o EPA must review and comment in writing on all EIS's issued by other Federal agencies. EPA comments, directed to the EIS-issuing agency, address both the adequacy of the EIS and the environmental impact of the proposed action.

- o EPA may refer to the Council on Environmental Quality those proposed major Federal actions which, through the EIS review process, EPA has determined to be unacceptable from the standpoint of environmental quality.

- o Also, EPA itself can have direct EIS preparation responsibilities for those of its actions (NPDES permit issuance, ocean dumping permits, wastewater treatment plant construction grants, etc.) which may have significant environmental impact.

The EIS preparation and review responsibilities of EPA are shared between the Office of Federal Activities (OFA) at the headquarters level and each of the regional offices. OFA serves as the principal reviewer for those EIS's having a national or programmatic scope or those which affect more than one EPA region. The Agency's regional offices generally coordinate the review of site-specific EIS's.

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APPENDIX G
CURRENT ENVIRONMENTAL RESEARCH IN
GEOTHERMAL ENERGY

Tables G-I and G-II summarize research now under way, sponsored largely by the Federal government. Table G-I comprises current and proposed ERDA-sponsored work. Table G-II, compiled from information furnished by Smithsonian Science Information Exchange, Inc., is more lengthy because it includes many efforts in which the environmental effect of geothermal energy plays one role in a much larger study and some that are program efforts rather than research itself. It does include work addressed to the environmental problems of water quality, noise, thermal pollution, and subsidence.

The Office of Radiation Programs of EPA recently prepared a Technical Note describing initial investigations of the radioactivity of geothermal waters in the western United States*. This report presents radiochemical data for 136 hot springs and shallow wells, and includes some brief remarks about potential activities involving human exposure.

The picture presented by current research appears to be a piecemeal attack on the problem, with many areas of concern addressed peripherally or omitted entirely.

It should be noted that MITRE is currently conducting a study for ERDA to provide a comprehensive compilation of research programs having geothermal applications. It is expected that this study will provide a more complete accounting of research efforts, including geothermally applicable projects stimulated by the problems of other energy sources.

*M.F. O'Connell and R.F. Kaufman, Radioactivity Associated with Geothermal Waters in the Western United States, Environmental Protection Agency, ORP/LV-75-8A, Las Vegas, Nevada, March, 1976.

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TABLE C-I

CURRENT ERDA ENVIRONMENTAL STUDIES

CONTRACTOR	TITLE	OBJECTIVE	FUNDING* FY 75	FY 76
Oak Ridge National Laboratory	Preparation of General Environmental Assessments for the Hydrothermal, Geopressured, and Hot Dry Rock Subprograms	Provide Independent Assessments of the Potential Environmental Impacts Associated with Pursuit of Geothermal Resource Development		73
Battelle-Pacific Northwest Laboratory	Removal of Hydrogen Sulfide from Geothermal Steam	Identify and Evaluate a Metaloxide Hydrogen Sulfide Removal Process for Geothermal Steam	50	185
Argonne National Laboratory	Guidelines to the Preparation of Environmental Reports for Geothermal Development Processes	Provide Reporting Guidelines to Those Persons Who Are Required to Submit Environmental Impact Information in Connection with ERDA-Supported Geothermal Projects		72
EIC, Inc. Newton, Mass	Control of Hydrogen Sulfide Emission from Geothermal Power Plants	To Develop a Wet Scrubbing Process Which Can Economically Reduce Hydrogen Sulfide Concentrations in Geothermal Steam	200	
Dow Chemical, USA	Investigation of Hydrogen Sulfide Removal from Simulated Geothermal Brines by Reactions with Oxygen	Evaluate a Hydrogen Sulfide Removal Process for Geothermal Brines		156
Lawrence Berkeley Laboratory	Subsidence in the Imperial Valley			
Los Alamos Scientific Laboratory	Hydrothermal Seismic and Ground Water Studies			
-	Geopressured Baseline Assessment - Seismicity, Subsidence, Etc.			

*In thousands of dollars.

TABLE G-1 (CONCLUDED)

CURRENT ERDA ENVIRONMENTAL STUDIES

CONTRACTOR	TITLE	OBJECTIVE	FUNDING* FY 75	FY 76
Lawrence Berkeley Laboratory	Geothermal Technology Environmental Impact Assessment	Focus on Effects in Nevada		
Sandia Laboratories	Sandia Magma Energy Research Project	Feasibility Study of Tapping Magma Sources; Attempt to Minimize Environmental Impact		

*In thousands of dollars.

TABLE G-II

CURRENT RESEARCH IN GEOTHERMAL ENERGY ENVIRONMENTAL IMPACT

SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	PROJECT TITLE	1975 FUNDING*	COMMENTS
Central Power & Light Co.	University of Texas	Geopressured Geothermal Investigations In South Texas	100	Environmental Impact Is One Aspect
EPA	Stanford Research Institute	Support of Advanced Energy R&D Program Planning for EPA	--	Geothermal Energy Included Among Other Resources
EPA	Industry and Environmental Research Laboratory	Survey of Environmental Regulations and the Assessment of Pollution Potential Control Technology Applications for Geothermal Resources Development	122	Description of Legal and Technological Requirements for Geothermal Pollution Control
EPA	Environmental Monitoring and Support Lab	Geothermal Systems: Environmental Assessment of Extraction, Conversion, and Waste Disposal	250	Focus on Development & Validation of a Monitoring Strategy for Effects on Plants, Animals, & Groundwater
FEA	RAND Corporation	Energy Alternatives for California	122	Geothermal Development Appears As Alternative to Alaskan Oil Importation
FEA	Radian Corporation	A Western Regional Energy Development Study--Executive Summary	--	Geothermal Energy and Environmental Impact as Aspects of Larger Study
FEA	Radian Corporation	A Western Regional Energy Development Study--Vol I, Analysis of Energy Scenarios	--	Geothermal Energy and Environmental Impact as Aspects of Larger Study
FEA	University of Oklahoma	Energy Alternatives - A Comparative Analysis	-- --	Geothermal Energy and Environmental Impact as Aspects of Larger Study

*In thousands of dollars.

TABLE C-II (Continued)

CURRENT RESEARCH IN GEOTHERMAL ENERGY ENVIRONMENTAL IMPACT

SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	PROJECT TITLE	1975 FUNDING*	COMMENTS
Ford Foundation	California Institute of Technology	Examination of Economic and Environmental Limits of Growth	500	Includes Geothermal Energy as Alternative Power Source
NASA, Space Science Office	NASA, Goddard Space Flight Center	Geological Investigations Using Landsat and Related Data	--	Remote Sensing of Environmental Factors Included
Netherlands Min. of Trans. and Public Works	Netherlands Commission on Remote Sensing Technology	Mapping by Remote Infrared Recording of Thermal Water Pollution	21	
New Mexico State Government	New Mexico State University	Geothermal Investigations in Southwest New Mexico	59	Addresses Water Chemistry and Potential for Pollution
NSF	University of Texas	Phase 0 Resource Management and Scope of Work Study for Generation of Electric Power-- Gulf Coast Geopressured Geothermal Resource	318	Establish Boundaries; Develop Preliminary Plans--Environmental Impact Is One Aspect
NSF, Adv. Energy Res.	Battelle, Northwest	Investigate the Nature and Environmental Impacts of Heavy Metals Released During Geothermal Energy Development	135	Concentrates on As, Hg, Sb, Se and Te at Geysers and Cerro Prieto
NSF, Adv. Energy Res.	Univeresity of New Mexico	An Economic and Environmental Evaluation of Solar and Geothermal Energy	86	Broad-Scale Evaluation of Social Costs
NSF, Adv. Energy Res.	Imperial City Government	Planning for Resource Development--Geothermal Engineering in Imperial County, California	364	City Government Study of Resource, Costs, Benefits, Policy Implications

*In thousands of dollars.

TABLE G-II (Continued)

CURRENT RESEARCH IN GEOTHERMAL ENERGY ENVIRONMENTAL IMPACT

SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	PROJECT TITLE	1975 FUNDING*	COMMENTS
NSF, Adv. Energy Res.	Systems, Science & Software	Geohydrological Environmental Effects of Geothermal Power Production - Phase II	200	Computer Model for Reservoir Behavior During Production
NSF, Research Applications	University of Colorado	Transport of Mass and Energy Due to Natural Convection The Geothermal Basin Problem	113	Addresses Subsidence and Seismicity
NSF, Adv. Energy Res.	Colorado School of Mines	Assessment of a Potential Geothermal Reservoir in the Basin and Range Province	198	Environmental Assessment As One Aspect
NSF, Adv. Energy Res.	California, State Division of Oil & Gas	Workshop on the Environmental Aspects of Geothermal Resources Development	58	California/Oregon Multi-Disciplinary Workshop
NSF, Adv. Energy Res.	St. Mary's College of California	Environmental Effects of Noise from Geothermal Resource Development	45	Measurement of Noise Levels, Auditory Damage, and Other Effects
NSF, Adv. Envir. R&T	Systems Control Technology	The Analysis of Subsidence Associated with Geothermal Development and its Potential for Environmental Impact	184	Imperial Valley
Pacific Gas & Electric Co.	Pacific Gas & Electric Company	Environmental Studies at the Geysers Geothermal Site, California	122	Geothermal Development Appears as Alternative to Alaskan Oil Importation
University of Texas	University of Texas	Geothermal Utilization Technology for Gulf Coast Geopressure Resources	--	Environmental Aspect Addresses Wastewater
USGS, Water Res. Div.	USGS, Woods Hole, Mass.	Hydrologic-Oceanographic Interrelations	29	Study of Transition Zone Between Fresh and Salt Water
USGS, Water Res. Div.	USGS, Sacramento, California	Subsidence and Related Aspects of Geothermal Systems	114	Establishment of Benchmarks and Surveying

*In thousands of dollars.
SOURCE: Smithsonian Science Information Exchange, Inc.

TABLE G-II (Concluded)

CURRENT RESEARCH IN GEOTHERMAL ENERGY ENVIRONMENTAL IMPACT

SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	PROJECT TITLE	1975 FUNDING*	COMMENTS
EPA	ERL	Identification of Components of Energy-Related Wastes and Effluents		Includes Geothermal Energy Among Other Source Types
EPA	National Institute for Occupational Safety and Health	Direct-Reading Personal Gas and Vapor Monitors	110	Includes an H_2S Monitor
EPA	National Bureau of Standards	Standard Reference Materials for Air and Water Pollution Monitoring	--	Segment of a larger effort
EPA	Oak Ridge National Laboratory	Instrumentation and Methods for Geothermal Source Related Effluents		Segment of a larger effort
EPA	Ames Laboratory USERDA Iowa State University	Development of Aqueous Effluent Instrumentation and Methods for Energy-Related Sources		Segment of a larger effort

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